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Parametric study of frequency selective surfaces at 5.8GHz using jerusalem cross for microstrip circular patch antenna

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Abstract—In this paper, the parameter which affect the gain and return loss characteristic of the microstrip circular patch antenna, the geometry of the frequency selective surfaces (FSS) elements is the most important one. In this following we study the effect of geometrical parameters of FSS element (W, w, a, l). Here microstrip patch antenna is placed over the layer of FSS. The objective in such design to analyze the return loss, gain and efficiency for microstrip patch antenna which operate at 5.8 GHz.In order to analyze all the parameter of the structure, HFSS software is used. To analyze the reflection coefficient magnitude and phase Ansoft designer software is used.

Keywords—FSS, AMC, PEC, Jerusalem cross, Microstrip patch antenna , Coax-feed method,Return loss,Gain.

I. INTRODUCTION

Recently, with the growing number of wireless applications, therehas been an increasing worldwide interest in low profile, low-cost,wideband system designs. One of the most intrinsic components ofwireless systems is their antenna. Microstrip patch antenna is the natural favorite due to its inherentadvantages of small size, low profile, lightweight, cost-effect, andits ease of integration with other circuits. However, it is well-knowthat a patch antenna on a dielectric substrate may have a verynarrow bandwidth due to surface wave losses. The surface waveexisted on the patch antenna will continue to propagate until itmeets a discontinuity. When the surface wave meets the discontinuity,it may radiate and couple energy to the discontinuity. Thesurface wave will reduce antenna efficiency, gain, and bandwidth.To achieve multi-band and wide-band operation in a patch antennadesign, the frequency selective surface (FSS) is implemented orimbedded in a patch antenna in recent years.FSS has a property that it reflect the plane wave in-phase and suppress the surface wave.FSS can be used as a filter, substrate and superstrate. In this designed FSS is used as a substrate.One of the oldest elements used in FSS work is the Jerusalem cross.Basically it consists of a pair of crossed dipoles with end loading.FSS is based on the resonance.

II. MICROSTRIP PATCH ANTENNA WITH FSS

As we know there are certain methods to increase the bandwidth of the microstrip patch antenna. First method increase height of the substrate. Second method use high dielectric constant.But in both the cases antenna efficiency will reduces due to surface wave losses .So in this paper FSS is used as a substrate for the patch antenna.Where PEC ground plane is replaced by the AMC(Artificial Magnetic Conductor) substrate. It has a property that its reflection coefficient magnitude is one and phase is zero.If normally designed patch antenna at 5.8GHz its bandwidth is near around 3.44% but when the patch antenna is designed on the AMC substrate the obtained bandwidth is near approx. 10.44% means 67% enhancement will be there.The another advantages is that the radiation efficiency is >85% for the entire bandwidth The dielectric material used for both the substrate is RT Duroid5880(the relative dielectric constant is 2.2) and the thickness chosen to be 3.16 mm for the lower substrate and for some upper substrate is 1.58mm .There is layer of jerusalem cross element in between the two substrate ,this whole structure is known as frequency selective surface. All the parameters (*a*, *l*, *w*, *W*) depicted in Figure 1.except*g*, areused as optimization variables. Where *W* and (*a*-*g*)/2 are length andwidth of the edge parts while *l* and *w* indicate the length and width of the straight portion of cross respectively.There are necessary steps is that W/l is less than .8. Wp is less than 4(a+l) so that patch cannot cross the ground plane. yf is less than Lp/2 so that feed cannot go beyond the patch. Coax-feed method is a very common technique used for feedingMicrostrip patch antennas.The inner conductor of the coaxialconnector extends through thedielectric and is soldered to the radiating patch, while theouter conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch inorder to match with its input impedance. This feed method is easy to fabricate and has lowspurious radiation.

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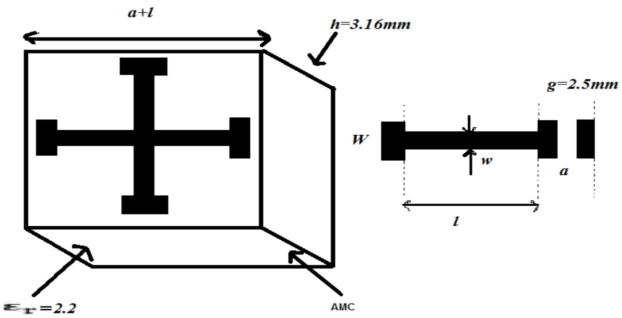

Fig. 1. The unit cell geometry for the JC –FSS on AMC

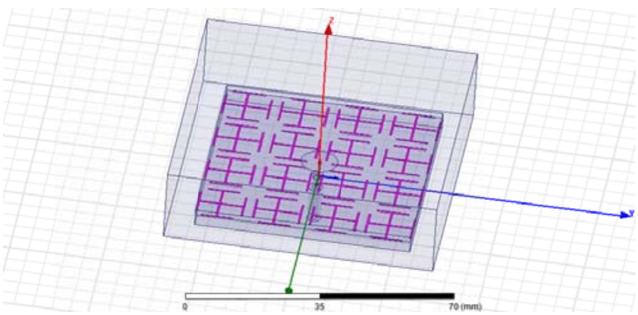

Fig.2. 4×4 finite array of Jerusalem cross frequency selective surfaces

This is an array of 4×4 Jerusalem cross frequency selective surfaces which is used as a substrate for the microstrip patch antenna.We know that in Jerusalem cross two crossing dipoles which are loaded with small, orthogonal sections at their ends.

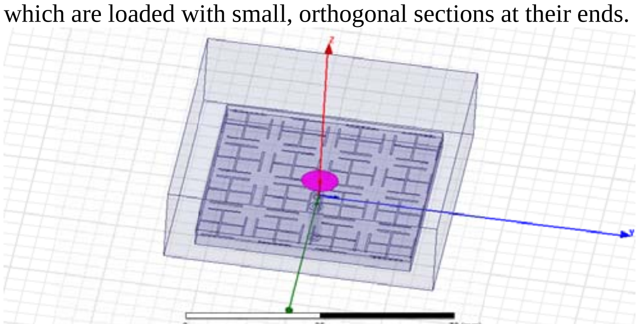

Fig.3. Circular Patch antenna over a 4×4 layer of FSS

The location of the feed probe yffor the patch antenna as well as dimensions of JC-FSS (w, W, a, l).Geometrical parameters of the antenna on AMC structure.Feedpointlocationisyf=5mm,width of the cross w=0.55mm, length of the edge part of cross W=8.5mm,a=4.31mm, length of the cross l=11.64mm.These are the reference values for the microstrip patch antenna and jerusalem cross element which operate at 5.8GHz. We observe that when an FSS ground plane is employed, with the same resonant frequency, we have nearly equal to 67% increase in bandwidth.

A. Analytical model

The effect of changing the geometricalparameters of the JC-FSS element on the antenna performance was outlined and quantified. We observed that on increasing Wanddecreasingwthe good matching characteristics shiftto lower frequencies.

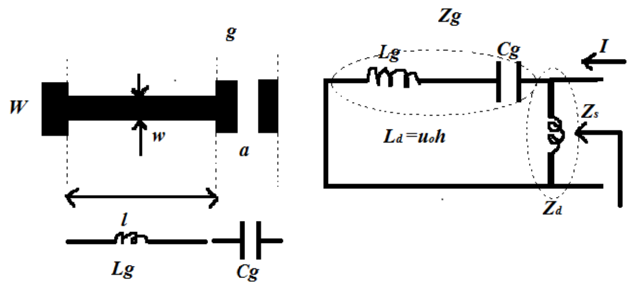

Fig. 4.Equivalent circuit model of JC-FSS unit cell

This is the circuit model is depicted along oneaxis. It is due to the fact that Jerusalem cross is a symmetric shapeand the performance is the same along both axis. the grid effective inductanceLgis, evidently, related to l andwwhereas the effective capacitance Cgis proportional to *W* and *a*.

B. Equations

$$fr = \frac{1}{2\pi\sqrt{\left(L_g + L_d\right)C_g}} \quad (1)$$

$$BW = \frac{\pi}{8\eta_o}\sqrt{\frac{L_g + L_d}{C_g}} \times \left(\frac{L_d}{L_g + L_d}\right)^2 \quad (2)$$

Where Lg is the grid effective inductanceand Cg is the effective capacitance .There is shift down in resonant frequency by changing (increasing the width of strip) the value of W. There is also effect on return loss and the gain of the antenna .On increasing the value of w, increase in resonant frequency will be there.

III. Simulated Results

After simulation it has been seen that resonant frequency, return loss has been shift than the reference parameter . In Fig 5,This is the return loss graph for the parameter of a which the maximum return loss and bandwidth is obtained at 5.8GHz for a=4.31mm. In Fig.6, This is the return loss graph for the parameter of W which the maximum return loss and bandwidth is obtained at 5.8GHz for W=8.5mm. In Fig .7,This

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is the return loss graph for the parameter of l which the maximum return loss and bandwidth is obtained at 5.8GHz for l=11.64mm.In Fig.8, This is the return loss graph for the parameter of w which the maximum return loss and bandwidth is obtained at 5.8GHz for w=.55mm. This is the return loss graph for the parameter of a which the maximum return loss and bandwidth is obtained at 5.8GHz for a=4.31mm.In Fig.9, This is the return loss graph for all the parameter (W,a,l,w) which the maximum return loss and bandwidth is obtained at 5.8GHz.In Fig.10, this is the graph of radiation efficiency which shows the 85% efficiency for entire bandwidth. In Fig.11,this is the plot of 2D radiation pattern which shows the maximum gain is 8dB at 5.8GHz .

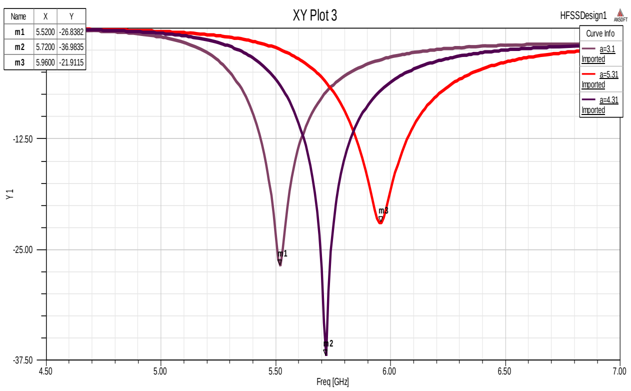

Fig.5. The graph shows the return loss and resonant frequency for 'a'

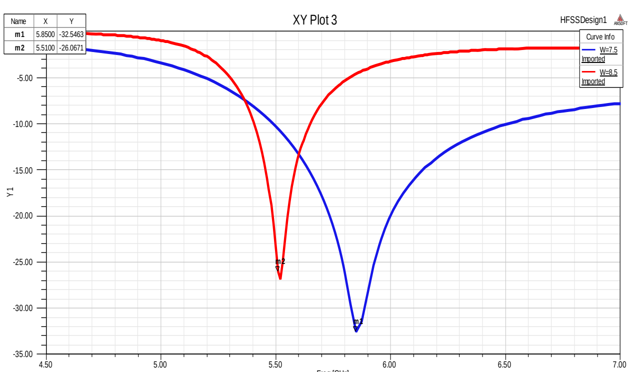

Fig.6. The graph shows the return loss and resonant frequency for 'W'

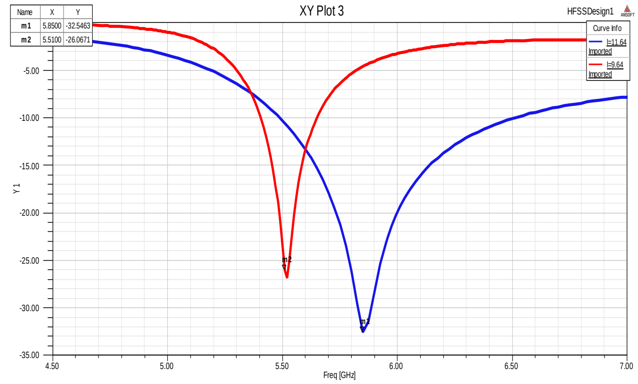

Fig.7. The graph shows the return loss and resonant frequency for 'l'

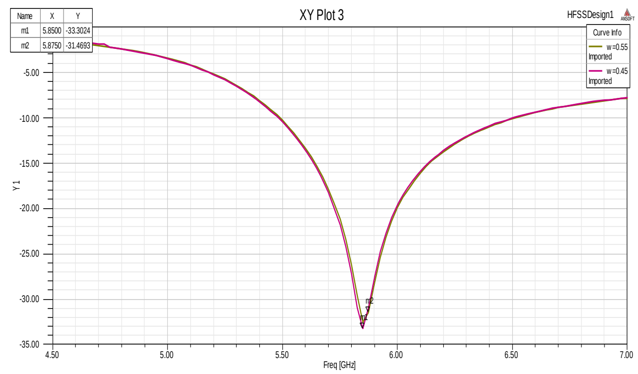

Fig.8. The graph shows the return loss and resonant frequency for 'w'

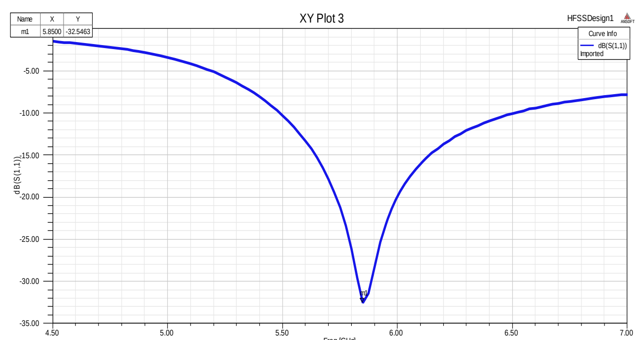

Fig.9. The graph shows the return loss and resonant frequency for (W,w,a,l)

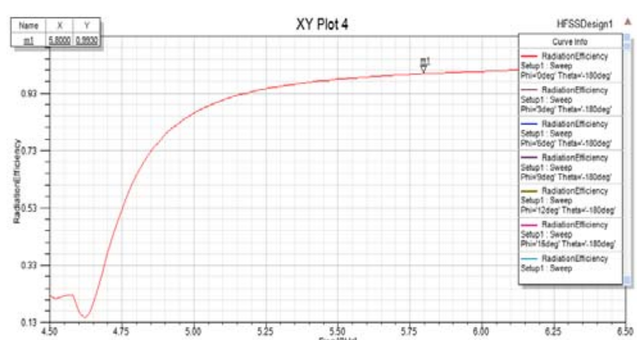

Fig.10. The graph shows the radiation efficiency of the antenna

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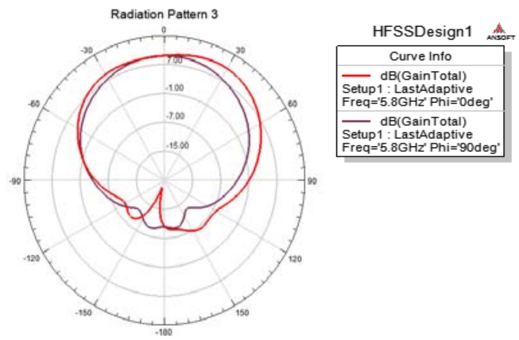

The table I shows thecharacteristic of circular patch antenna which operate at 5.8GHz frequency its gain is 8dB ,Bandwidth is 1GHz , efficiency is 99.30% and return loss is -32.546dB.

TABLE I

Characteristic	My results at 5.8GHz
Gain	8dB
Bandwidth	1GHz
Efficiency	99.30%
Return loss	-32.546dB
Resonant frequency	5.8GHz

CONCLUSION

In this paper a novel design of artifcial magnetic conductor substratefor bandwidth enhancement of patch antenna and the analysis of varying the parameter of the element of jerusalem cross on the gain, return loss, front-to-back ratio and resonant frequency is analyzed.Makinguse of the High Impedance Surfaces, mutual coupling between the antenna and its image is reduced dramatically which results is easy impedance matchingover a relatively wide bandwidth as well as total power reflection thatcreates the desired front-to-back ratio. The structure of microstrip patch antenna is implanted over the FSS which operate at 5.8GHz as a reference frequency by which we compare the shift of all the value or antenna parameters. Artificial Magnetic Conductor (AMC) Antenna design hasbeen derived using the IWO invasive weedoptimizationwith a view to improve the bandwidth.

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