ISSN 2348 – 8034
Impact Factor- 3.155

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

Design of Microstrip Array Antenna with E-Shaped DGS Structure

MISS BORHADE MEGHANA VIJAY*1 and PROF. MRS.DHEDE V. M.[2]
[*1]Student ME (Signal Processing), JCOE, KURAN, PUNE, INDIA
[2]PhD (Registered), JCOE, KURAN, PUNE, INDIA

ABSTRACT

In this paper, I have designed a single patch antenna and 4x1 array antenna with E-Shaped DGS structure at operating frequency 2.4 GHZ for Wireless application. The antenna is simulated using High frequency structural simulator (HFSS) software. The results for performance parameters of simulated single patch micro strip antenna in terms of Bandwidth, Gain, Voltage standing wave ratio and Return loss are 80MHz, 3.5db,1.41,-15.48db respectively. The results for performance parameters of antenna with E-shaped DGS structure in terms of Bandwidth, Gain, Voltage standing wave ratio and Return loss are 404 MHz, 7db,1.17,-22.12db respectively. Practical results for proposed antenna for Bandwidth, gain, voltage standing wave ratio and return loss are 340 MHz, 6.75db, 1.14, -22.87db respectively. The proposed antenna is designed on FR4 substrate having dielectric constant as 4.4.

Keywords: *Array, Return loss, Bandwidth, Voltage standing wave ratio.*

I. INTRODUCTION

Recently, the microstrip patch antennas are increasing their importance in wireless communication system .For different operating frequencies; microstrip antennas are having different applications in communication system depending on its different advantages such as light weight, low volume, low cost, planar configuration, reliability etc. Microstrip patch antennas are having some disadvantages also. The disadvantages are Low Gain and narrow bandwidth.

These disadvantages of microstrip antennas can be removed by applying different Structures in antenna design.

a) Defected ground structure (DGS)
b) Electromagnetic band gap structure (EBG)

By applying these structures we can improve the bandwidth parameter of microstrip patch antenna.By applying Array structure the gain parameter can be improved. DGS structure is having many advantages over EBG structure. These structures are basically used to obtain the fun ctions such as unwanted frequency rejection and circuit size reduction [3]. In this paper, E-shaped DGS is introduced in 4x1 array antenna .or Defect in the ground plane is introduced .Depending on the shape of the defect and its size, the current distribution in the ground plane is disturbed and result in controlled excitation and propagation of electromagnetic wave through the substrate. The Defect can be change from simple shape to the complex one depending on the performance requirement [4].

DGSs have many advantages over EBG or PBG structure.

1) For implementing EBG structure large area is needed to implement the periodic pattern and also it is difficult to define the unit element of EBG [5].
2) The geometry of DGS can be one or few etched structure which is simpler and does not need a large area to implement it [6].
3) DGS is more easily to be designed and implemented and has higher precision with regular defect structures [7].

In this paper, The design of single patch antenna, 2x1 array antenna, 4x1 array antenna with and without DGS is shown. Also the comparison between these antennas in terms of VSWR, bandwidth, gain, return loss, % bandwidth etc.

II. DESIGN SPECIFICATIONS

TABLE I. DESIGN SPECIFICATION OF PATCH ANTENNA

Parameters	Specifications
Substrate	FR4
Dielectric Constant	4.4
Substrate height	0.6 mm
Operating Frequency	2.4 GHz
Feeding technique	Microstrip Line Feeding

In this paper microstrip array antenna is designed using FRe substrate.The E-shaped DGS Stucture is added in the design to improve the bandwidth parameter of antenna and array structure is introduced to improve the gain parameter of antenna.

A)Software design

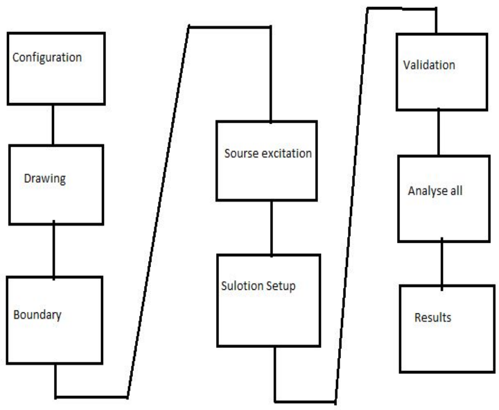

Figure 1.Step for designing in HFSS

b) Mathematical Design

Structure of single patch antenna with inset feed is shown in figure 2. The Antenna is composed of patch, substrate, ground and feeding network. The performance of antenna generally depends on dimensions of above components and the operating frequency. The mathematical equations for single patch antenna are given below.

Step 1: Calculation of the Width (W):
The width of the Microstrip patch antenna is given as:

$$W = \frac{c}{2f_r\sqrt{\left(\frac{\varepsilon_r+1}{2}\right)}} \qquad (1)$$

Where;
c - Free space velocity of light, 3 x 10^8 m/s
fr - Frequency of operation
ε_r - Dielectric constant

Step 2: Calculation of Effective dielectric constant (ε_{reff}): The effective dielectric constant is:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left\{1+12\frac{h}{w}\right\}^{1/2} \qquad (2)$$

Where;
ε_r - Dielectric constant
h - Height of dielectric substrate
W - Width of the patch

Step 3: Calculation of the Effective length (L_{eff}):
The effective length is:

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \qquad (3)$$

Where;
c - Free space velocity of light, 3 x 10^8 m/s
f_r - Frequency of operation
ε_{reff} - Effective dielectric constant
Step 4: Calculation of actual length of patch (L):
The actual length is obtained by:

$$L = L_{eff} - 2\Delta L \qquad (4)$$

Where,
L= Actual length of patch.
L_{eff} = Effective length.
ΔL= Small difference between length.

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)} \qquad (5)$$

We get ΔL=0.70mm, For W=36.4mm,
h, =1.54mm, εreff=3. Hence the length the of the patch is, L= Leff- 2ΔL=28.4 mm
Step 5: Calculation of feed point-
For this feed would be given L/4 distance.
Feed point (y0) =28/4=7mm, y0=7mm

$$Z= \frac{377}{\sqrt{er}(w/t+2)} \qquad (6)$$

Where z=50Ohm.

We get Wf=2.84mm

The Length of quarter-wave transformer is,

Feed Length (FL)= λg /4*sqrt(4.4) = 14.5 mm

Fl=14.5mm

Step 6: Calculation of Substrate

For this design this substrate dimensions are

Ls=L+2*6h=28+2*6*1.6=58mm

ISSN 2348 – 8034
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Ws=W+2*6h=38+2*6*1.6=66mm

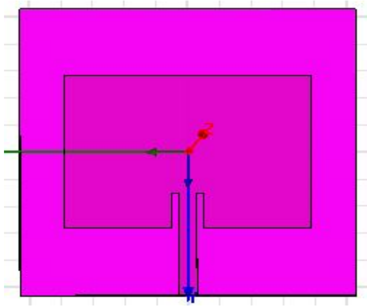

Figure2. single patch antenna

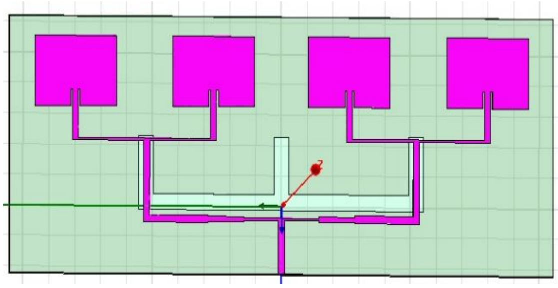

Figure3. 4x1 Array with E-Shaped DGS structure

B) Hardware design

The fabrication process involves 5 steps as describe below:

1) Generate mask on transparency-

First step is to transfer the EM structure from the Microwave Office software to Auto-Computer Added Drawing (AutoCAD) and print it onto the transparency film.

2) Photo exposure process-

Second step is the Ultraviolet exposure process. It is done to transfer the image of the circuit pattern with a film in a UV exposure machine onto to the photo resist laminated board. The process took about 120 seconds (2 minutes).

3) Etching in developer solution-

The third step is to ensure the pattern will be fully developed, during the developing process. The photo resist developer solution was used to wash away the exposed resist for about 10 minutes. Then the solution was removed by spray wash. In this process, water was added with Sodium Hydroxide (NaOH).

4) Etching in Ferric Chloride

It will remove the unwanted copper area and this process was followed by the removal of the solution by water. This process took about 30 minutes to be done.

5) Soldering the probe-

The final step was to solder the probe, where the board was dried and rubbed
with sand paper to remove the remains of the unexposed resist pattern area. Upon fabrication, the SMA connector was soldered to the microstrip antenna.

Figure 4. Proposed 4x1 Array antenna with E-shaped DGS structure

III. SIMULATED VS PRACTICAL RESULTS

A) Results and Discussion

a)VSWR for single patch antenna

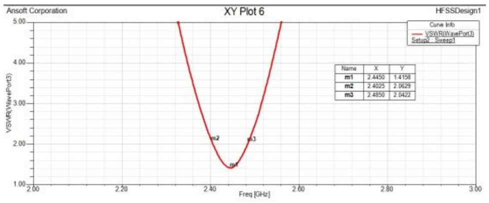

Figure5. VSWR graph

b)Return loss of single patch antenna

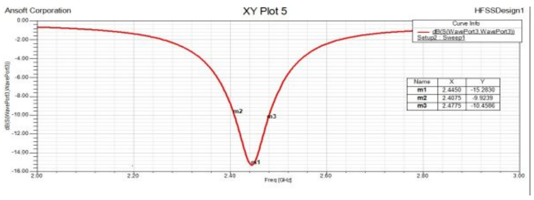

Figure 6.Return loss plot

c) Radiation Pattern for single patch antenna

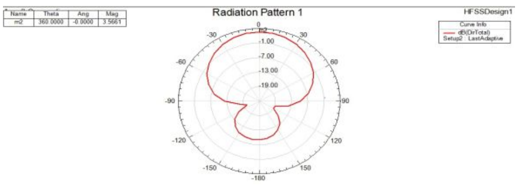

Figure 7.Radiation pattern graph

d)VSWR for 4x1 Array antenna with E-shaped DGS structure

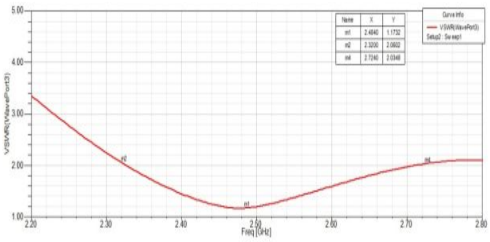

Figure 8. VSWR Plot for 4x1 array with DGS

e) Return loss for 4x1 array with DGS

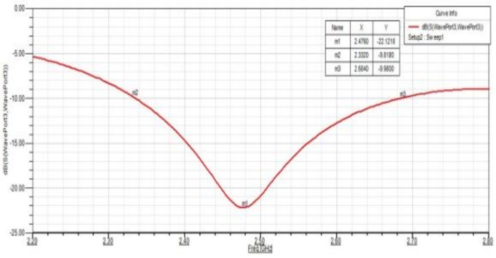

Figure 9. Return loss Plot

f) Radiation Pattern for 4x1 Array with DGS

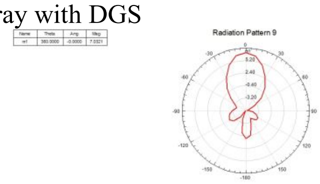

Figure 10. Radiation Pattern Plot

B) Comparison between Single patch antenna and 4x1 array antenna with E-shaped DGS structure

Table2. Comparison between single patch antenna and 4x1 array antenna with E-shaped DGS structure

Sr. no.	Type of MSA	Freq (GHz)	Return loss(dB)	VSWR	B.W. (MHz)	Gain (dB)
1.	Single patch	2.44	-15.28	1.41	80	3.50
2.	4x1 Patch array with DGS	2.47	-22.12	1.17	404	7.00

IV. CONCLUSION

A 4x1 planar array antenna with DGS structures has been designed, simulated and compared with the single patch antenna. It has been shown that theproposed 4x1 planar array antenna with DGS structures hasoutperformed the single patch antenna Thesimulation results have shown that the 4x1 planar arrayantenna with DGS structure has gain of 7dB,the return loss of -22.12dB that corresponds to VSWR of 1.17 at operating frequency of 2.4 GHz.

V.ACKNOWLEDGEMENT

I would like to express my gratitude to all those who helped us to completethis work. I want to thank my guide Prof. Mrs. Dhede V. M. for her continuoushelp and generous assistance. she helped in a broad range of issues from givingme direction, helping to find the solutions.

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ISSN 2348 – 8034
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