Controlling the Gain and Frequency using Dielectric Resonator in Microstrip Patch Antenna

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Abstract— The increasing use of wireless and satellite communication systems demand the antennas for different systems and standards with properties like reduced size, broadband, multiband operation, moderate gain etc. The planar and dielectric resonator antennas are the present day antenna designer's choice. However, conducting microstrip patch antennas inherently have a narrow bandwidth. In this dissertation, controlling the gain and frequency using DRA in microstrip patch antenna is done. The simulation has been done by using software Ansoft HFSS 15.0. The proposed design uses a rectangular ground plane and the squares of DRA and FR-4 substrates are placed alternatively above the ground plane. The antenna uses FR-4 (εr=4.4) and DRA (εr=12) as a substrate material to achieve wide bandwidth. Microstrip line feed has been used for feeding the antenna. The patch is of a square shape having side 6mm. study and results demonstrate the proposed antenna is competent enough to work in the Ku band (12-18) GHz. The antenna has a ground size of 50×50 mm2 and offers impedance bandwidth of 6.3 GHz covering the entire Ku band.
Key words: DRA, Ku band, FEM, HFSS

I. INTRODUCTION

In recent years the abbreviation of antenna has acknowledged much consideration in various applications such as wireless portable devices, which assist the antenna engineers to design compact size antennas. Also microstrip antenna usually offers high metallic losses at Ku band for satellite communication and radar application. The DRA can be a commendable choice for these demands as it controls the problem of high losses due to the dearth of metal. DRA generally made up of dielectric materials of high dielectric constants (10-100) for microwave applications. It is a volumetric radiator and has larger aperture area than microstrip antenna and gives high radiation efficiency.

Small size, wide bandwidth, high radiation efficiency and dearth of surface waves are some advantages of Dielectric Resonator Antenna over Microstrip Patch Antenna [1], [2]. In the literature, numerous shapes such as cylindrical, hemispherical, rectangular and ring have been presented [3], [4], [5], [6], [7]. Since the rectangular shaped DRA offers advantage like they are easy to fabricate and have more design flexibility so it is more easy and common over cylindrical and hemispherical shape [3], [7]. Furthermore, a number of excitation methods [8] for coupling energy to DRAs have been investigated such as the slot aperture, coaxial probe, microstrip line [9], co-planar line and dielectric image guide. DRA antennas have also some disadvantages such as low gain, narrow bandwidth and low efficiency.

The paper presents a frequency controller antenna which obtains three different frequencies from a single antenna. The gain also varies according to the frequency. This antenna can be used for the satellite communications. The main objective is to enhance the gain of an antenna as well as controlling of gain and frequency by minimum change in its structure. The proposed antenna is simulated using FEM based HFSS simulator and the return loss, VSWR, radiation patterns and gain are observed.

II. ANTENNA DESIGN

The geometry of the proposed antenna during the simulation process is shown in Fig. 1. It consists of a rectangular ground plane. Squares of dielectric resonators and FR-4 substrate are placed alternatively above the ground plane. The gray colored squares are of dielectric resonator material which is having ε_r=12 and the green colored squares are of the FR-4 material which is having ε_r= 4.4. Thirteen slabs of Dielectric resonator and FR-4 have placed alternatively above the ground.

The DRA design has a substrate thickness of 0.8mm. Dielectric resonator (ε_r=12) and FR-4 (ε_r=4.4) are used. DRA is chosen of rectangular shape with dimensions 18×9.75mm2. Dielectric material with high dielectric constant is used. High dielectric constant material improves coupling and reduces the size but also lowers Bandwidth. The Different dimensions of the patch, ground plane, width of the patch and substrate are described in table 1.

The Dielectic resonators and FR-4 are of square shape having dimension 6mm. A microstrip line feeding is used of size 28.5×1.12 mm^2. Although no any design formula are accurately given and the hit & trial method is used to enhance the performance. However approximate modeling DRA has been done using following mathematical relations that gives the approximate idea for designing of the DRA [10]. The DRA size (length, width & height) of the DRA can be approximated by the relation given below such that (l > w > h):

$$DRA_{size} \propto \frac{\lambda_0}{\sqrt{\epsilon_r}} \quad (1)$$

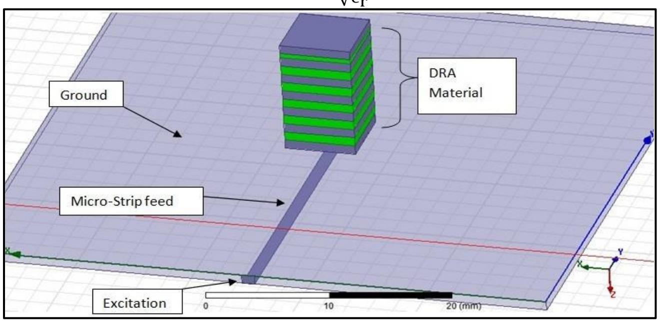


Fig. 1: Antenna view during simulation process

Size of the patch	Square (side= 6mm)
Size of the feed line	28.5×1.12 mm2
Thickness of the substrate	0.8 mm
Material used	(i) DRA (ε_r= 12) (ii) FR-4 (ε_r=4.4)
Length of the ground plane	50 mm

Width of the ground plane	50 mm
Ground slot shape	Rectangular (18×9.75 mm^2)
Feeding method	Microstrip line feed

Table 1: Design specification of the proposed antenna

The substrate thickness of the antenna is given as,

$$h_s = \frac{0.3c}{2\Pi f\sqrt{\varepsilon_s}} \quad (2)$$

Total height of a DRA can be calculated by,

$$h_t = h_{dra} + h_s \quad (3)$$

Where, $h_{dra} = \frac{\lambda_0}{4\sqrt{\varepsilon_{dra}}}$

The stub length can be given as,

$$L_{stub} = \frac{\lambda_g}{4} \quad (4)$$

The guide wavelength of the DRA is given as,

$$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_{reff}}} \quad (5)$$

The slot dimensions are approximated as,

$$w_s \approx 0.2 l_s \quad (6)$$

$$l_s \approx \frac{0.4\lambda_0}{\varepsilon_{reff}} \quad (7)$$

The effective dielectric constant of the DRA is given as,

$$\epsilon_{reff} = \frac{h_t}{\frac{h_{dra}}{\epsilon_{dra}} + \frac{h_s}{\varepsilon_s}} \quad (8)$$

The feedline dimensions can be approximated by

$$\frac{L_f}{W_f} \approx 3.96 \quad (9)$$

Fig 2 shows the flowchart of the simulation process:

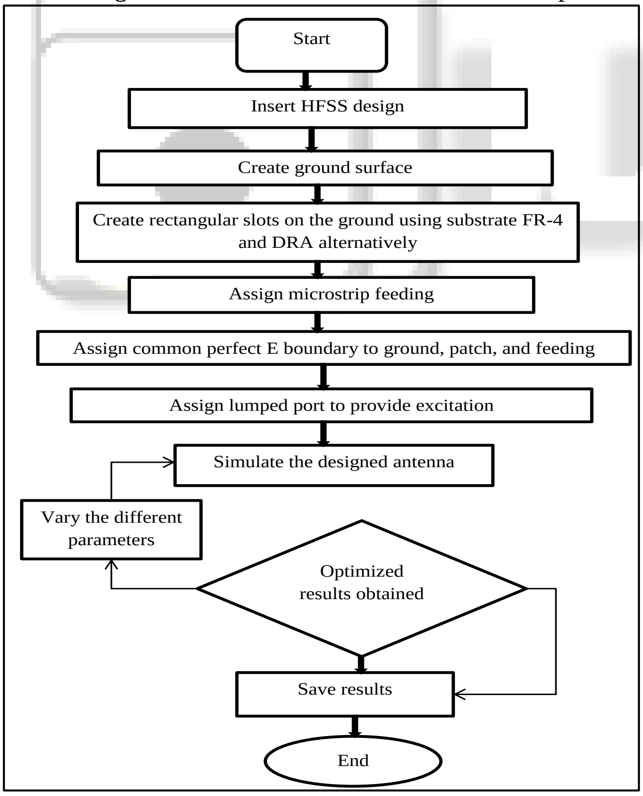


Fig. 3: Flowchart of the simulation process

A. *Simulation Process*

Following steps have to be taken for the design of a microstrip antenna.

1) *First step*
- Choose the model solution type of the structure that has to be analyzed.
- Draw the substrate dimensions.
- Draw the patch and trace on the top face of the substrate.
- Draw the ground either on top or bottom of the substrate.

2) *Second step*
- Select the substrate to assign the material.
- Assign a user defined material.

3) *Third step*
- Select the patch and the ground and assign the perfect E boundary to them.
- Create a microstrip line feed in XZ plane.
- Give excitation to the microstrip line port.

4) *Fourth step*
- Add solution setup.
- Give frequency sweep, number of passes, solution type etc.

5) *Fifth step*
- Create far field setup for radiation pattern.
- Create an air box around the design.
- Assign radiation to air box.

6) *Sixth step*
- Analyze the proposed design.
- Simulate the proposed design.
- Seventh step:
- Plot return loss, VSWR and current distribution.
- Plot radiation patterns at various resonance frequencies.

III. Results

After optimization, the proposed geometry was analyzed. Fig. 4 shows return loss curve of the proposed Dielectric Resonator Antenna for Ku band. The simulated impedance bandwidth of the proposed antenna is found to be 11-17.3 GHz with an area of 50×50 mm^2. Proposed antenna shows three resonance frequencies 14.7, 15 and 15.9 GHz.

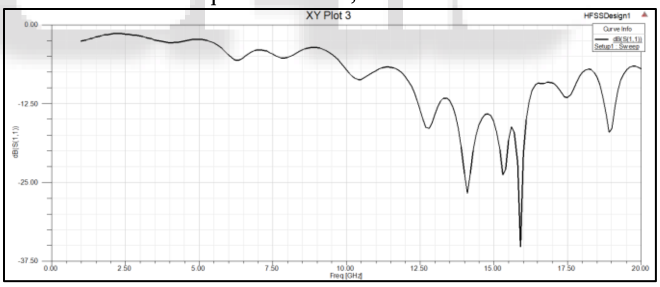


Fig. 4: Simulated return loss (S11) of the proposed antenna

The main objective of the proposed antenna is to obtain three different frequencies from a single antenna so that it is like a frequency controller antenna. Figure 5 shows the return loss v/s frequency plot after removing the fifth and third slab from the antenna.

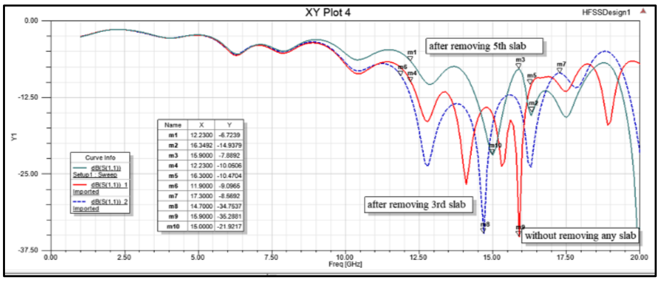


Fig. 5: The return loss v/s frequency plot

Fig. 6 shows the simulated VSWR curve for the proposed antenna. The range of VSWR is from 1 to ∞. If the load is perfectly matched to the source the value of VSWR would be 1.For satisfactory operation of antenna, VSWR should be in between 1 and 2. It shows the VSWR remains in between 1 and 2 in the entire band of operation i.e. 11-17.3 GHz.

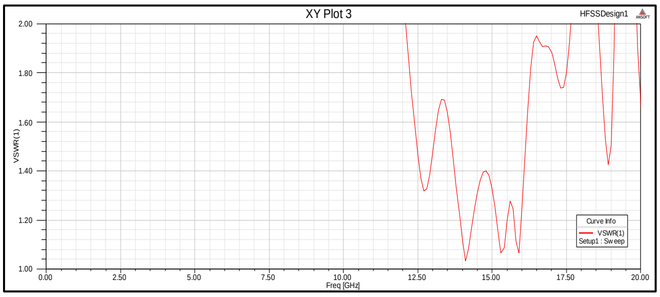
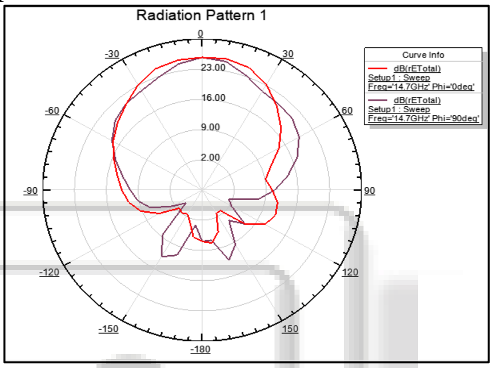


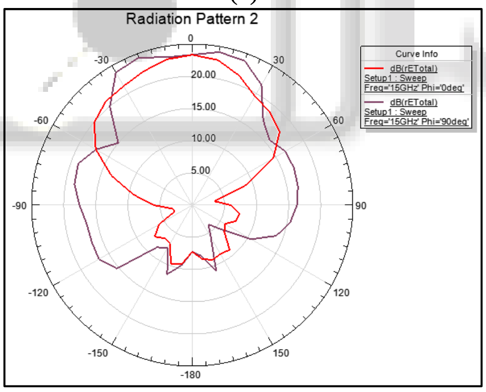
Fig. 6: Simulated VSWR of the proposed antenna

Initially, we take center frequency of the frequency band as solution frequency. From the return loss curve, we get three resonance frequencies i.e. 14.7, 15 and 15.9 GHz.

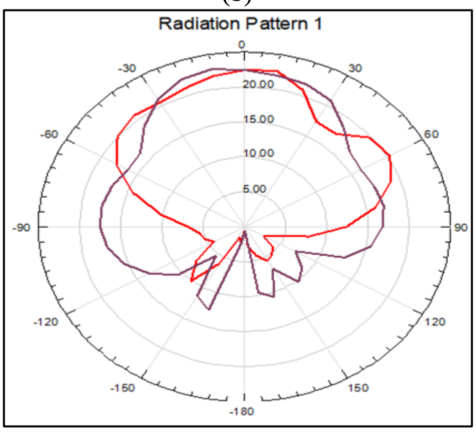
At these frequencies, we plot radiation pattern. Fig. 7 shows radiation patterns at three resonance frequency for the proposed antenna.



(a)



(b)



(a) 14.7 GHz (b) 15.0 GHz (c) 15.9 GHz

Fig. 7: Radiation patterns of the proposed antenna

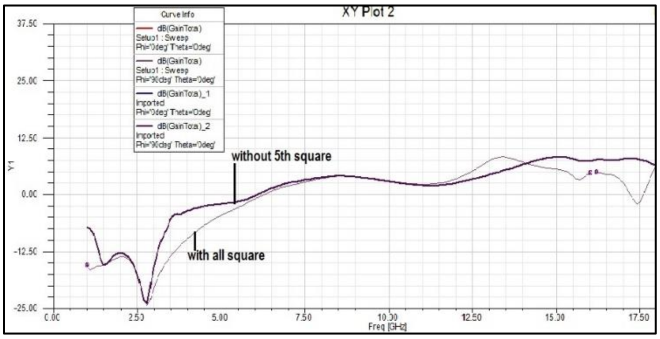


Fig. 8: Gain vs. Frequency plot of the proposed antenna

The gain vs. frequency plot of the proposed antenna is shown in Figure 8. The gain of the proposed antenna varies according to the frequency. The fig shows the variation in frequency and gain with putting all the slabs and after removing the fifth slab.

IV. Conclusion

In this dissertation, controlling the gain and frequency using DRA in microstrip patch antenna is done. The simulation has been done by using software Ansoft 15.0. The designed antenna results have been obtained i.e. the return loss of -35.28 dB at 14.7 GHz, -21.92 dB at 15.0 GHz and -35.28 dB at 15.9 GHz. In the entire band of operation, the VSWR is between 1 and 2. The simulated results of the antenna show stable radiation patterns over entire Ku band. The good impedance matching characteristic and directional radiation patterns over the entire operating bandwidth of 11-17.3 GHz (6.3 GHz) make this antenna suitable candidate for Ku band applications and systems.

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