IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
ISSN: 2278-2834, ISBN: 2278-8735. Volume 4, Issue 3 (Nov. - Dec. 2012), PP 36-40
www.iosrjournals.org

Gain Enhancement of Circular Microstrip Patch Antenna Using Dual-FSS Superstrate Layer for ISM Band

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Abstract: *In this paper, an effort is made to optimize the gain to show better performance analysis on the basis of design and simulation results by implementing FSS structured superstrate layer with circular microstrip patch antenna at operating frequency of 5.8 GHz for ISM Band applications. In this proposed antenna, co-axial feeding technique is utilized in order to have better impedance matching effects. In order to show our results better, we have made a comparative analysis with conventional microstrip patch antenna at the same frequency band to increase the gain, directivity and minimize the return loss of the desired antenna. In addition to this, it shows the advantages of utilizing the ism band and fss superstrate layers compared to other frequency bands. Full wave 3-D simulation results is carried out by using Ansoft based HFSS software, that is, based on Finite Element Method (FEM) modeling technique.*
Keywords*:Microstrip Antenna, FSS, ISM Band, Co-axial Feed, Impedance Matching. Directivity, Return Loss.*

I. Inroduction

In the field of RF communication, Frequency Selective Surface (FSS) plays an important role in enhancement of gain that are periodic surfaces combination of identical elements in one or two-dimensional construction designed as a electromagnetic filter in order to avoid interference of transmission and reception of signals in the microstrip antennas. Two basic characteristics of FSS are Narrow Bandwidth and Periodicity in two dimensions [1]. FSS has become an alternative to the fixed frequency meta-material; where static geometries and spacing of unit cells determine the frequency response of a given met material. FSS was first developed to control the transmission and reflection characteristics of an incident radiation wave. This has resulted in smaller cell size along with increases in bandwidth and the capability to shift frequencies in real time for artificial materials. In this paper, we proposed a dual FSS Superstrate Layer with circular microstrip patch antenna at operating frequency of 5.8 GHz for ISM Band applications which provides the enhancement of gain and minimization of return loss .The main purpose of using fss on superstrate layer is to provide protective shield for microstrip patch antenna to reduce insertion losses and also, acts as a conducting patches to transmit better radiating signals in order to achieve desired antenna's efficiency. In addition, the use of FSS superstrate layer makes the antenna much easier to fabricate via the use of etching processes.

II. Antenna Design Analysis

Microstrip antenna is also called printed circuit antenna or patch antenna. When conformal and low profile antennas are requested, the microstrip antenna is the best choice. This type of antenna also has the advantage of low cost and weight, reproducibility, design flexibility and ease of installation [10]. The modes supported by the circular patch antenna can be found by treating the patch, ground plane, and the material between the two as a circular cavity.

The procedure assumes that the specified information includes the dielectric constant of the substrate (ε_r), the resonant frequency (f_r) and the height of the substrate h. The procedure is as follows:

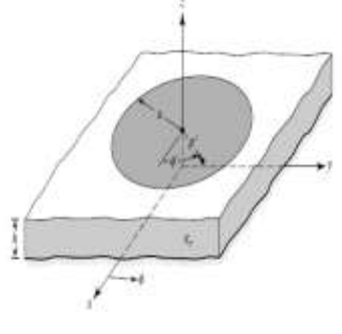

Figure 2.1: Geometry of Circular Patch Antenna.

2.1 Actual Radius and Effective Radius of Circular Patch Antenna:
Since the Dimensions of the patch are in the circular form, the actual radius of the circular patch antenna is given by:

$$a = \frac{F}{\left\{1 + \frac{2h}{\Pi \varepsilon_r F} * \left[\ln\left(\frac{\Pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ (1)$$

Where

$$F = \frac{8.791 \times 10^9}{f_r * (\varepsilon_r)^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Eqn.1 does not take into account the fringing effects.. But for the rectangular patch, fringing makes the patch look electrically larger and it was taken into account by introducing a length correction factor. Similarly for the circular patch a correction is introduced by using an effective radius a_e , to replace the actual radius$a$**:**

$$a_e = a * \left\{1 + \frac{2h}{\Pi \varepsilon_r a} * \left[\ln\left(\frac{\Pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \quad \ldots\ldots\ldots\ldots\ldots(3)$$

2.2 Resonant Frequency:
The Resonant Frequency for the dominant mode TM^z_{110} should be modified by using effective radius a_e and expressed [9] as:

$$f_r = \frac{1.841\ c}{2\pi a_e \sqrt{\varepsilon_r}} \quad \ldots\ldots\ldots\ldots\ldots.(4)$$

III. Antenna Design Specifications

The Proposed Circular Microstrip Patch Antenna (CMPA) by integrating Dual FSS Superstrate Layer at operating frequency of 5.8 GHz was designed by using the following specifications:

Table-3.1: Design Specifications of Circular Microstrip Patch Antenna with Dual FSS Superstrate Layer.

PARAMETERS	VALUES
Frequency Band Used:	ISM Band
Operating Frequency(fo):	5.8 GHz
Substrate Material used:	RT-Duroid 5880 tm
Substrate Dielectric Material:	2.2
Substrate Thickness:	0.762 mm
Radius of Circular Patch:	9.88 mm
Feeding Technique Used:	Probe Feeding Technique
FSS Layer above Superstrate:	FR-4 epoxy
FSS Layer below Superstrate:	RT-Duroid 5880 tm
FSS Radius above Superstrate Layer:	R = 2.5 mm
FSS Radius below Superstrate Layer:	R = 2.0 mm
Feed Point Location from Centre:	3.1 mm from Centre
Air-Gap Height b/w Substrate & Superstrate	28.96 mm

IV. Antenna Proposed Structure

In this Proposed Structure, we have employed a Circular Microstrip Patch Antenna (CMPA) with and without using Dual FSS Superstrate Layer at Resonant Frequency of 5.8 GHz (for ISM Band).In order to design, simulate and analyze this structure properly by using the above design specifications, we have implemented Ansoft Based HFSS version 12.0 Software. The Basic Features related to HFSS Software:

1. HFSS stands for High Frequency Structure Simulator and is a commercial finite element method solver for electromagnetic structures.

2. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters.
3. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University. Prof.Cendes and his brother Nicholas

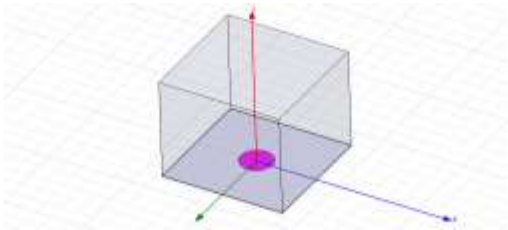

Figure-4.1: Conventional Circular MicroStrip Patch Antenna HFSS in HFSS Software

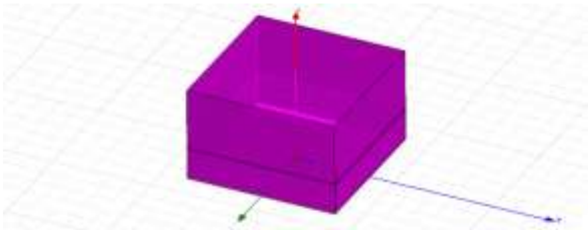

Figure-4.2: Proposed Antenna Structure in Software.

V. Simulation Results & Discussion

5.1 Simulation Results of Normal Circular MicroStrip Patch Antenna without Dual FSS Layer:

5.1.1Return Loss:

1.Operating Frequency: 5.8 GHz
2.Value of Return Loss (in db): -13.7496 db
3.Peak Point (m1) of Operating Frequency: 5.7889 GHz

5.1.2 Gain Total:

1.Operating Frequency: 5.8 GHz
2.Value of Gain Total (in db): 7.1479 db
3.Peak Point (m1) of Operating Frequency: 5.7789 GHz

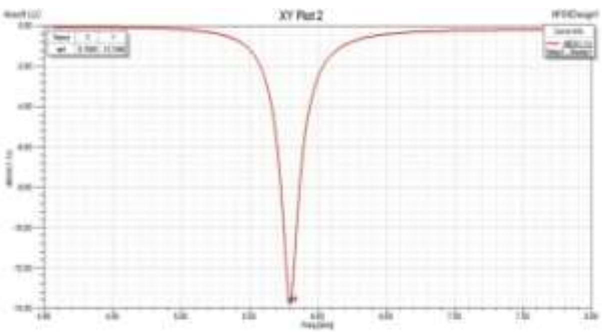

Figure-5.1.1: Return Loss (in db) without Dual FSS FSS

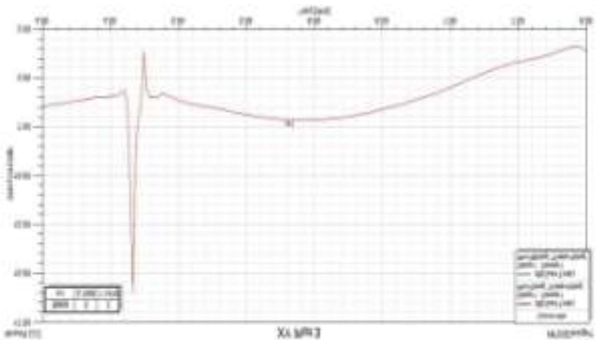

Figure-5.1.2: Gain Total (in db) without Dual

5.1.3 Radiation Pattern:

1. Operating Frequency: 5.8 GHz
2. Setup1: Sweep1
3. Peak Point (m1) of Operating Frequency: 5.77899 GHz
4. Phi (in degree) = 0 degree; Phi (in degree) = 90 degree

5.1.4 Directivity:

1. Operating Frequency: 5.8GHz
2. Setup1: Sweep1
3. Peak Point (m1) of Operating Frequency:
4. Phi (in degree) = 0 degree ; Phi (in degree) = 90 Degree

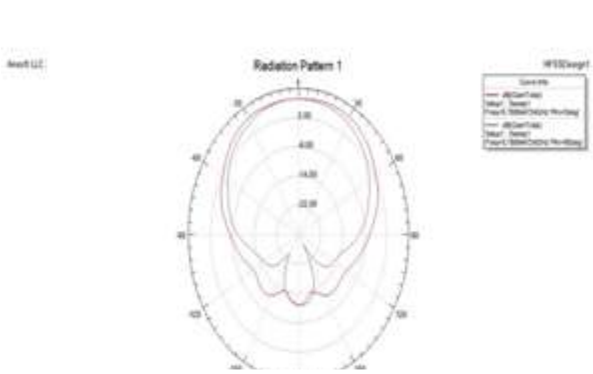

Figure 5.1.3: Radiation Pattern without Dual FSS

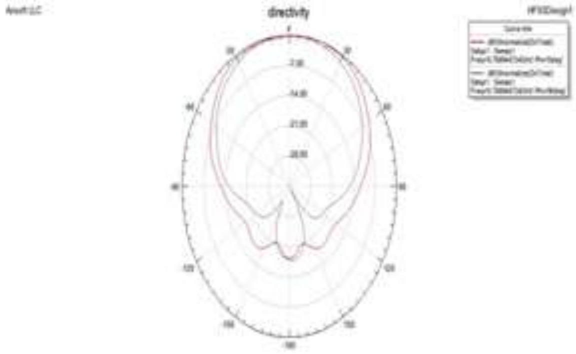

Figure 5.1.4: Directivity without Dual FSS

5.2 Simulation Results of Circular MicroStrip Patch Antenna with Dual FSS Layer:

5.2.1Return Loss:

1. Operating Frequency: 5.8 GHz
2. Value of Return Loss (in db) : -19. 5858 db
3. Peak Point (m1) of Operating Frequency: 5.7889 GHz

5.2.2 Gain Total:

1. .Operating Frequency: 5.8 GHz
2. Value of Gain Total (in db): 10.9146 db
3. Peak Point (m1) of Operating Frequency: 5.8090 GHz

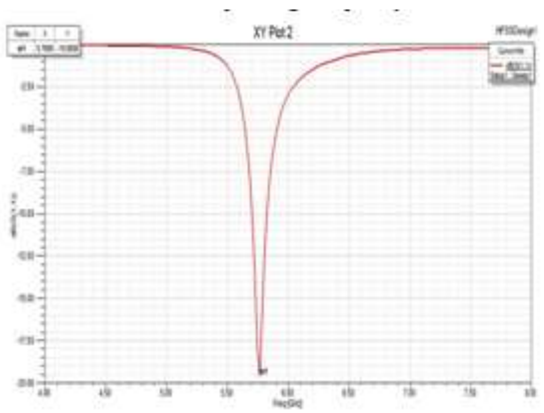

Figure 5.2.1 Return Loss (in db) with Dual FSS

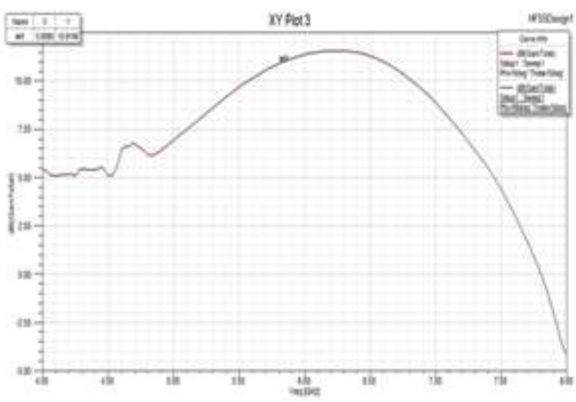

Figure 5.2.2 Gain Total (in db) with Dual FSS

5.2.3 Radiation Pattern:

1. Operating Frequency: 5.8 GHz
2. Setup1: Sweep1
3. Peak Point (m1) of Operating Frequency: 5.8020GHz
4. Phi (in degree) = 0 degree; Phi (in degree) = 90 degree

5.2.4 Directivity:

1 .Operating Frequency: 5.8 GHz
2. Setup1: Sweep1
3. Peak Point (m1) of Operating Frequency: 5.77899 GHz
4. Phi (in degree) = 0 degree; Phi (in degree) = 90 degree

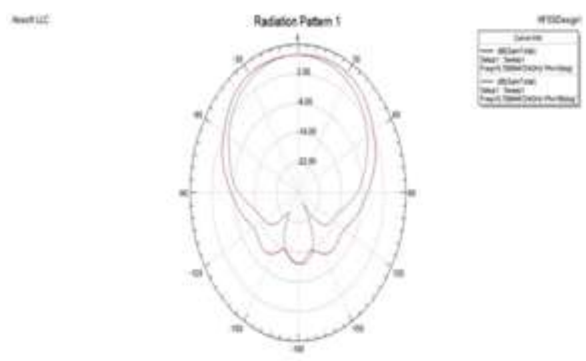

Figure 5.2.3: Radiation Pattern with Dual FSS

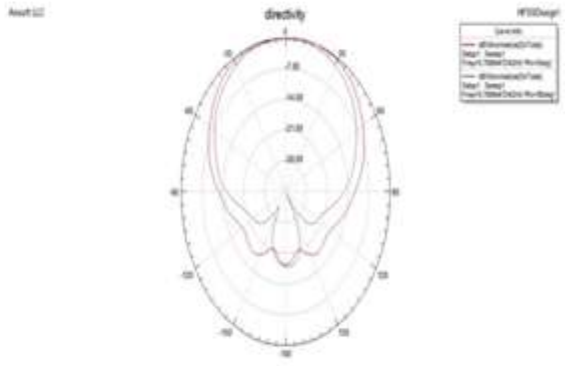

Figure 5.2.4: Directivity with Dual FSS

VI. Conclusion

In this paper, design and simulation of dual fss superstrate layer composed with circular patch antenna provides better performance analysis through enhancement of gain, directivity and minimization of return loss. In this proposed antenna, circular slots of fss layer with lower radius size (in mm) worked as better radiation and minimum reflection of signals which increases antenna's efficiency. Secondly, it acts as a protective shield (i.e. dielectric radomes) against various insertion losses for circular microstrip patch antenna. To this proposed antenna system, about 52.7% increment in gain and around 42.47% minimization of return loss is achieved. Simulation results are carried out by using Ansoft based HFSS version12.0 software.

Acknowledgement

The Authors express their appreciation to Dr. R.L Yadava, Professor and Mr. Deepak Gangawar, Asst.Professor, Department of Electronics and Communication, Engineering, Galgotia's College of Engg. & Technology (G.C.E.T), Greater Noida (U.P) for their technical support and valuable advices.

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