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# Analysis of substrateintegrated frequency selective surface antenna for iot applications

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## ABSTRACT

Antennas are long used for communication of data since a century and their usage has been diversified over the past two decades and the antennas also entered the domain of medical fields. A rectangular microstrip patch antenna has been designed on a substrate integrated waveguide with frequency selective surface which is in the shape of a square. The design of this antenna with SIW are done by using CST on a low cost FR4 substrate where $\epsilon r$ =4.4, h=1.58 mm and tan $\delta$=0.0035. The SIW structure merit is utilized on the traditional FSS is simulated and verified by using CST.

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## 1. INTRODUCTION

From so many years antennas are used in medical applications like medical implants, hyperthermia treatments, microwave imaging and wireless wellness monitoring system. The main aim of this antenna which are used in these medical applications are to reduce the size, power consumption and as well as the complexity. The antennas that are ultilised for these medical applications are very heavy which alter the characteristics of an antenna, so a novel antenna is required in the medical filed. The first FSS was developed by Guglielmo Marconi in the early 1900's. FSS are in use for many years to filter electromagnetic waves by using the periodic array interface of multiple material, metallic elements and or a combination of both on the incident plane. A frequency selective response is created by the incident plane there by filtering certain frequencies while letting others pass through. Even though this definition is extremely broad, all the possible combinations of periodic arrays of identical elements ca be broadly classified under two distinct flags, dipole array and slot array as shown in Figure 1 [1].

The physical phenomenon on how they operate is the same even if they have diversity in the geometry of their construction. When an incident plane wave hits the dipole array of FSS, it leads to excitation of metallic element with electric currents causing the electrons in the metallic elements to start oscillating. This electron oscillation will in turn start producing its own EM fields thus functioning as an array of tiny radiating antenna. A frequency selective response is produced when the metallic element interfers with the plane wave which is incidented [2-8].

The concept of slot array and dipole array are same and the only difference is that is in dipole array unlike slotted array instead of inducing oscillating electric currents on metallic elements, the incident plane wave induces oscillating magnetic currents on the periodic metallic surface. These oscillating magnetic currents on the metallic surface in turn cause the surface to start radiating its own fields [9-13].

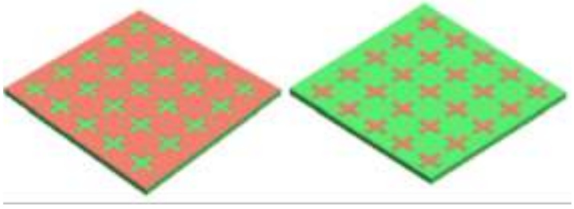

Figure 1. Slotted array & Dipole array

An interesting relation can be identified between the dipole and slot array frequency selectivity surfaces. Mostly the dipole array behaves like a Band-Stop Filter thereby allowing only a selective type of frequencies where as its complimentary slot array behaves like a Band-Pass Filter [14].

The rapid development of research on Substrate Integrated Waveguide (SIW) technology implies people's strong eagerness on implementation and integration of microwave and millimetre-wave components and wireless communication system. As we know that these waveguides and co-aial lines provides low loss that is these are used very widely and also consume huge power compared to low power applications like micro patch antennas and other wearable electronics [15-18]. Substrate Integrated Waveguide (SIW) as shown in Figure 2.

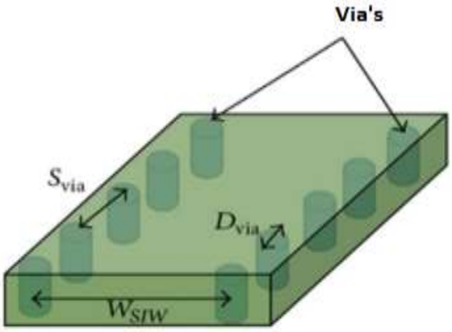

Figure 2. Substrate Integrated Waveguide (SIW)

SIW is a combination of planar structures like micro strip line where as non-planar structures like waveguide structures. These Waveguide structures are implemented by using vias (or) holes. These SIW structures are not only having the advantages of microstrip but also having the waveguide properties [19-21].

It also allows integration of passive components like antenna and active components like amplifier on a single substrate hence eliminating the transitions between them and reducing losses and parasitic effects in return. There are two metal plates on the top and bottom of the substrate, and certain metalized via holes are used to connect them. This kind of structure is easy to fabricate through PCB technology [22-23].

Therefore, the merit of the FSS and SIW together are exploited to realise the performance improvement in terms of gain of an antenna to be used in biomedical applications [24].

## 2. RESEARCH METHOD

SIW FSS consisting of planar periodic micro strip square patch structure design is discussed in this section. Design optimization of micro strip antenna and SIW antenna are presented along with the different shapes in which they produce different type of frequency responses. The factors that are affecting the frequency selective surface are geometry, conductivity, substrate material and as well as the polarization of that antenna [25]. Schematic of patch antenna and Schematic of SIW FSS as shown in Figures 3 and 4.

The proposed microstrip patch antenna with FSS is designed at 2.4GHz on a FR4 substrate with relative permittivity of 4.4 and thickness is1.58mm and tan $\delta$=0.0035. The parameters of the antenna along with the values are shown below. Design parameters of rectangular path antenna and design parameters of rectangular path antenna as shown in Tables 1 and 2.

Table 1. Design Parameters of Rectangular Path Antenna

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| A1 | 54.16 (mm) | B1 | 63.65 (mm) |
| A2 | 29.68 (mm) | B2 | 29.78 (mm) |
| A3 | 5.58 (mm) | B3 | 0.4 (mm) |
| A4 | 10 (mm) | B4 | 2.6 (mm) |
| B | 6.18 (mm) | | |

Table 2. Design Parameters of SIW FSS

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| X1 | 20 (mm) | X5 | 9.2 (mm) |
| X2 | 18.5 (mm) | X6 | 8 (mm) |
| X3 | 16.4 (mm) | X7 | 6.4 (mm) |
| X4 | 10.8 (mm) | | |
| $V_D$ | 0.6 (mm) | Distance between the holes | 1 (mm) |

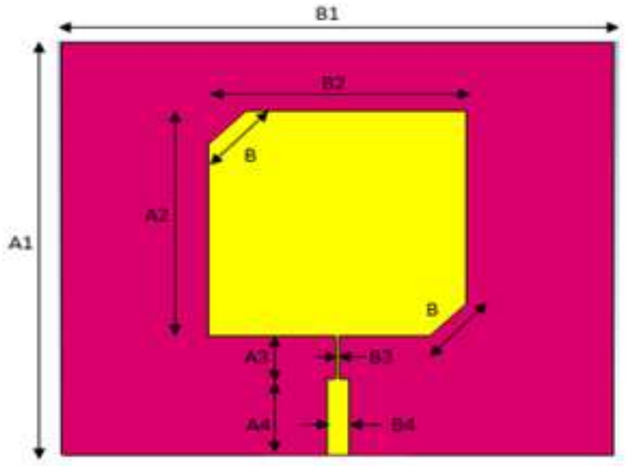

Figure 3. Schematic of Patch antenna

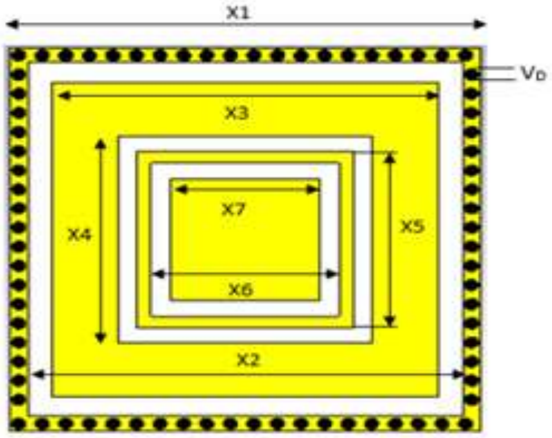

Figure 4. Schematic of SIW FSS

The transmission characteristics of the substrate integrated wave guide are similar to that of the normal waveguides. The distance between the holes are very small to prevent the leakages and losses of radiation mechanism. The material used in designing of vias in SIW is pure copper. The thickness of SIW is 1.58mm [2]. 3D view of patch antenna with SIW FSS as shown in Figure 5.

From the Figure 5 it is observed that the microstrip antenna and FSS are overlapped together as shown in the above figure. The optimum distance between the SIW FSS and the micro patch antenna is found to be 10 mm for 2.4 GHz FSS structure.

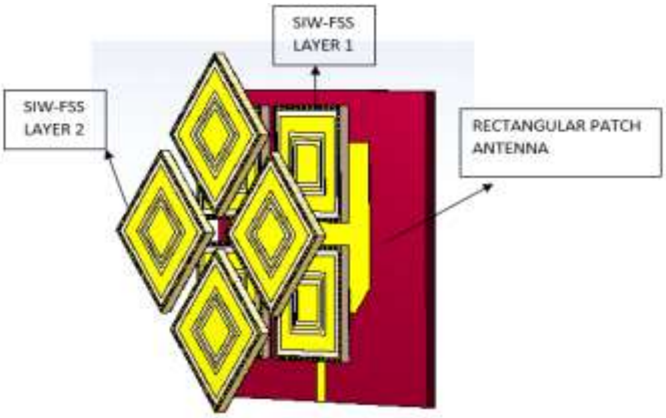

Figure 5. 3D view of patch antenna with SIW FSS

The SIW FSS results and studies for different distances showed the optimum distance between the first SIW FSS layer and patch antenna is D1= 10mm and the optimum distance between the first SIW FSS layer and the second SIW FSS layer oriented 450 with respect to the first layer is D2= 10mm. Front view & side view of patch antenna and SIW FSS as shown in Figures 6(a) and 6(b).

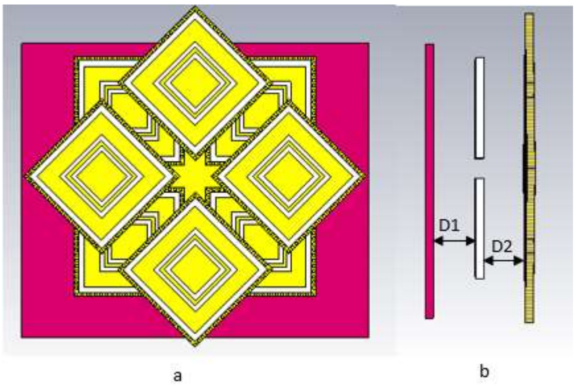

Figure 6. (a) front view & (b) side view of patch antenna and SIW FSS

## 3. RESULTS AND ANALYSIS

Performance of an antenna is verified by the parameters like return loss, radiation pattern and gain. Those parameters are observed for microstrip patch antenna, and for the microstrip patch antenna with the single layer and dual layer frequency selective surface. The parameters are shown for each and every element with the help of their following diagrams.

### 3.1. Return Loss

In general return loss is defined as the power reflected from an antenna due to discontuinity in the transmission line. The return loss should be less than unity and a reference of -10dB is taken for any antenna. For microstrip patch antenna the return loss of -31dB is obtained at 2.4GHz and -25dB at 2.4GHz for microstrip patch antenna with single layer FSS and -12dB at 2.4GHz for microstrip patch antenna with dual layer FSS. Band width of 74.47MHz is obtained for microstrip patch antenna with dual layer FSS. Return loss of the rectangular patch antenna, single element SIW FSS and rectangular patch with dual layer SIW FSS as shown in Figure 7 till 9.

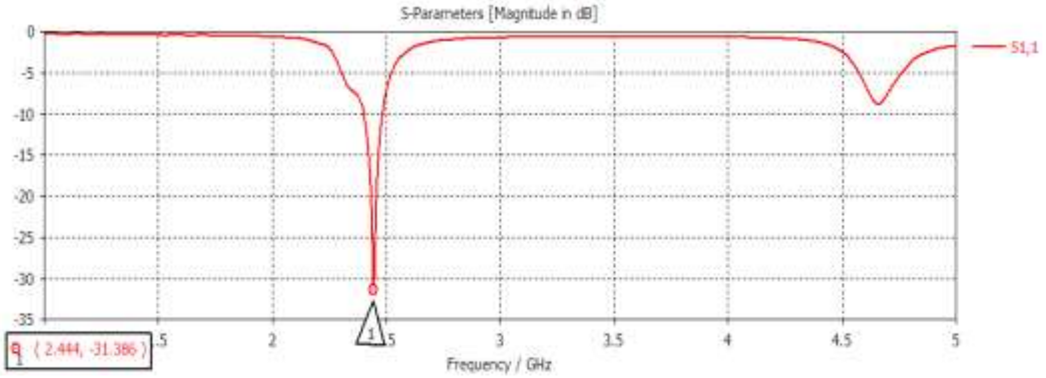

Figure 7. Return loss of the rectangular patch antenna

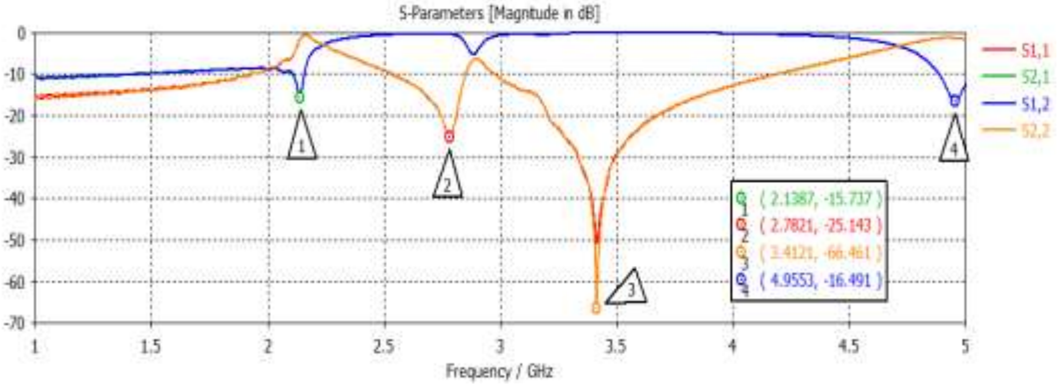

Figure 8. Return loss of single element SIW FSS

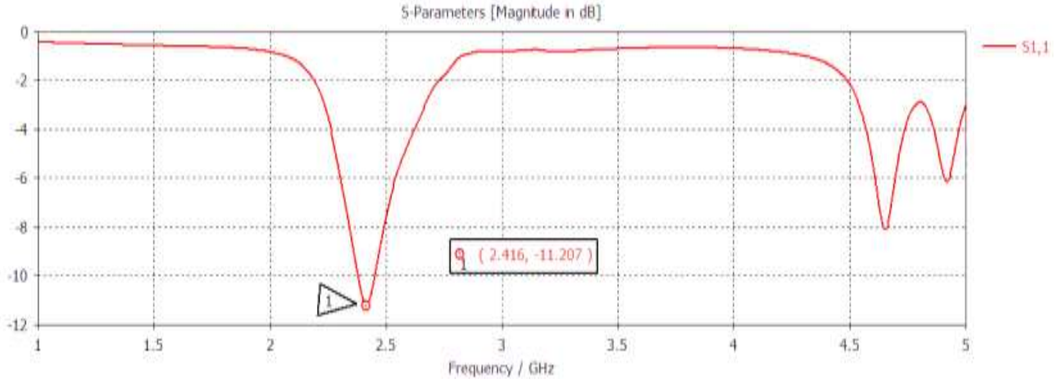

Figure 9. Return loss of rectangular patch with dual layer SIW FSS

### 3.2. Radiation Pattern & Gain

The variation in the power radiation of antenna as a function of spatial co-ordinates i.e. elevation angle (ϴ) and the azimuthal angle (ɸ) is defined as radiation pattern. The above mentoned antenna is showing circular polarization at a frequency range of 2.4GHz.

One of the most important parameters for an antenna is the gain and for an ideal antenna the gain should be 3dB. For the microstip patch antenna the gain is 2.39dB at 2.4GHz. To improve the gain of this antenna a dual layer SIW FSS has been designed. A gain of 6.03dB is obtained for dual layer FSS at 2.4GHz without any shifting in the resonant frequency and the bandwidth is also improved. Radiation pattern and gain of rectangular patch antenna and with with dual layer SIW FSS as shown in Figures 10 and 11.

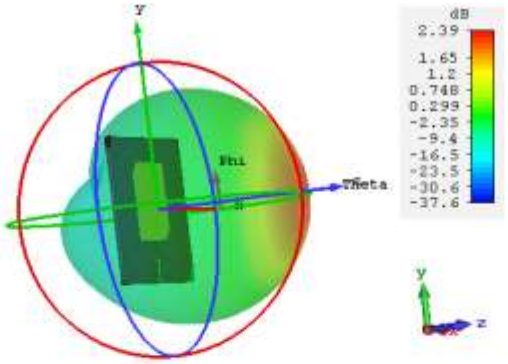

Figure 10. Radiation pattern and gain of rectangular patch antenna

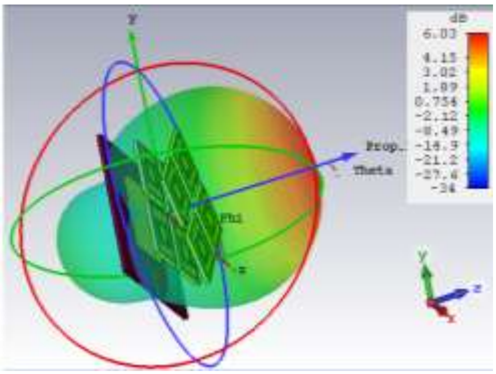

Figure 11. Radiation pattern and gain of rectangular patch antenna with dual layer SIW FSS

## 4. CONCLUSION

The SIW FSS microstrip patch antenna is designed at 2.4GHz and the parameters of those antenna are measured. It is observed that by adding an affordable cost and simple design of the substrate integrated waveguide frequency selective surface to the patch antenna the gain of an antenna is improved from 2.39dB to 6.03dB which is suitable for many medical applications.

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