Multi-layer FSS for Gain Improvement of a Wide-Band Stacked Printed Antenna

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***Abstract*— In this paper, an attempt has been made to improve the gain of a wide-band antenna using two layers of frequency-selective surfaces. It is seen that using two layers it is possible to achieve flat transmission characteristics over a reasonable bandwidth. However with an actual antenna, the gain improvement has at present been achieved over only a small band. It is expected that with further optimization and possibly increasing the number of layers, wide-band gain enhancement can be achieved.**

***Keywords*— Frequency Selective Surface (FSS), Gain enhancement, Patch Antenna, Electromagnetic Band gap (EBG)**

I. INTRODUCTION

Frequency Selective Surface is widely used in spatial filtering and concept of spatial filter is first introduced in [1]. The filter is designed to suppress the undesired radiation in order to sharpen the radiation patterns and, hence, enhance the directivities of antennas of interest, such as a dual-band dual-polarized antenna, a wideband directive antenna, and an array antenna with grating lobes [2]. Gain enhancement using single layer FSS superstrate was studied in [3] and using multilayer in Ultra wide band(UWB) was studied in [4]. FSS is also used for protecting WLAN component from different electromagnetic (EM) frequency [5-8].

FSS is made up of metallic lines and slots. Its resonance frequency depends on inductor and capacitor created by meander line and straight line respectively. Resonance frequency depends on thickness of line, substrate permittivity and its thickness and dimension of unit cell. We saw that as the size of unit cell increases its produce multiple resonant frequency. Hence for good operation size of unit cell should be very small as compare to wavelength used for operation. As we know X-band is very popular in Radar application. In this paper, using the multi-layer FSS we have increased the gain of antenna in X-band (10-12.4GHz). Since unit cell FSS used here is having very high Q-factor [3], hence to enhance the 3-dB bandwidth and make it becomes more flat we used multi-layer FSS. The multi-layer FSS used is not enhancing bandwidth much but it makes the bandwidth flat by reducing Q-factor. Multilayer FSS is simulated on CST microwave studio and distance between two layers are optimized and finally 3-dB bandwidth is measure using Horn antenna WR-90 which gives 2.4GHz bandwidth (10-12.4GHz).Here simulation and measure result is good agreement with each other.

FSS is partially reflecting surface. When it is used with patch antenna with ground plane then some reflected wave from FSS is re-reflected from ground plane and distance between FSS and ground plane is adjust in such a way that it add in phase at the FSS surface. This leads to gain enhancement of Patch antenna at that resonant frequency. When double-layer FSS is used then it follows lens properties shown in fig.1. In double layer FSS each FSS behave as lens and antenna work as a source. When EM wave passing through single layer it bents toward normal [3] and becomes parallel, when it passes through another FSS then it converges towards normal direction and hence gain due to multi-layer FSS is increased.

II. FSS UNIT CELL CHARACTERISTIC

The unit cell used in this paper is shown in fig.2 [3]. It is simulated on CST microwave studio and its resonant frequency is 10.8GHz. Dimension of this unit cell is 3.5 x 3.51 mm^2 (0.126 λ_o X 0.126 λ_o). Substrate used has ε_r =3.2 and thickness 0.762 mm. Black pattern shown in fig.2 indicates metal plate.

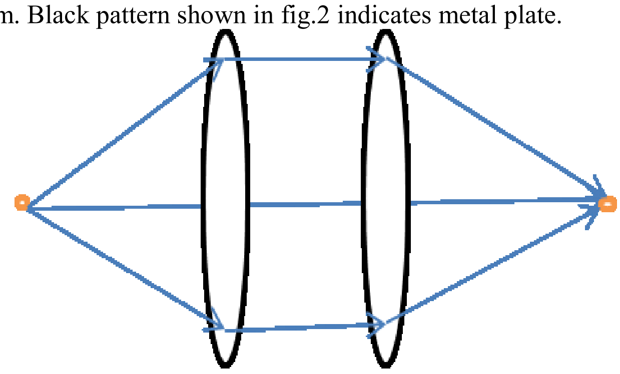

Fig 1 Schematic diagram of two lenses

This unit cell properties and its characteristic was studied and it was found that FSS is polarization independent [3]. In this paper we investigate about multilayer FSS to enhance the bandwidth and its flatness in pass-band. Simulation set up of double layer FSS is shown in fig.3. Each single layer resonates at same frequency 10.8GHz in case of double layer FSS shown in fig.3 which gives optimum wide bandwidth by adjusting the distance between the two layers.

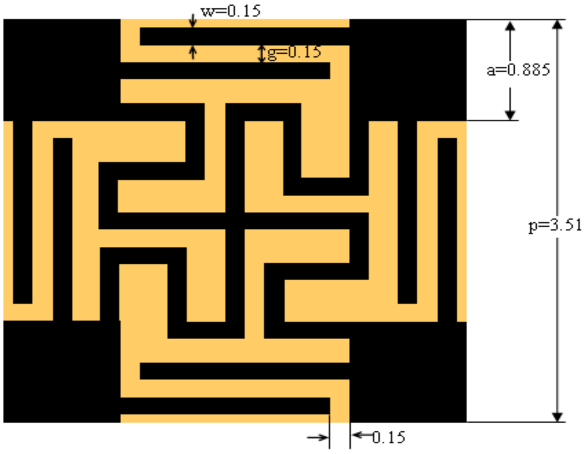

Fig 2 unit cell of FSS (dimension are in mm)

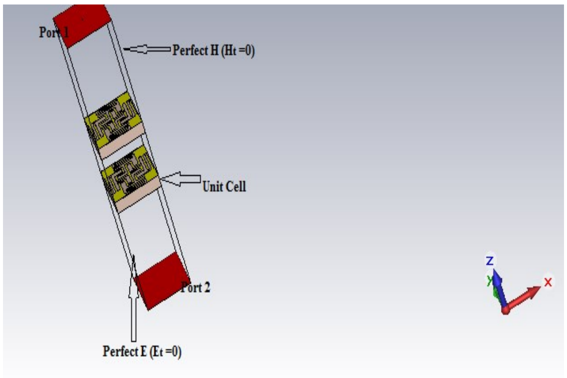

Fig 3 simulation setup in CST microwave studio

The electromagnetic waves propagation is normal to the plane of the unit cell. Electric boundaries (E_t=0) are applied at x_{min} and x_{max} of the structure whereas magnetic boundaries (H_t=0) are applied at y_{min} and y_{max}. Since it is very difficult to simulate large array structure this E_t, H_t boundary condition applied is used to simulate periodic structure. It is seen from $|S_{21}|$ of simulation results (Fig 4), that the proposed FSS screen is transparent to frequency 10-12.5GHz i.e. 3-dB bandwidth is 2.5GHz and return loss in this frequency band is below -10dB.

Taking d as a parameter which indicate gap between two FSS and for different d variation simulation result of S11 and S21 is shown in Fig. 5 .If double layer FSS placed closer to each other then bandwidth increases but its return loss performance starts degrading and if they are two far from each other then bandwidth is decreasing.. Hence gap between two FSS are optimized and optimized distance between two FSS was found to be d=3mm where maximum bandwidth and desirable return loss are achieved shown in fig. 4. This wide bandwidth is more flat in pass-band as compare to single FSS and also cutoff frequency in stop-band is sharp. Hence it can be used in radome application.

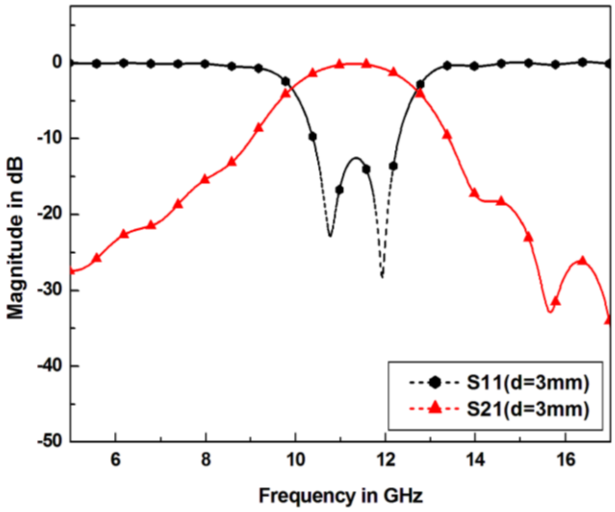

Fig.4 simulated result of optimized gap (d=3mm) between double layer FSS

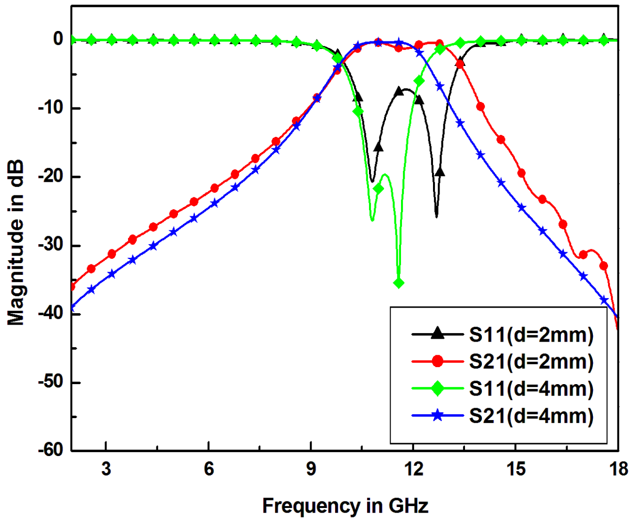

Fig.5 comparison of double layer FSS with different d

III. ANTENNA WITH FSS

For enhancing gain in wide frequency using FSS, a stacked antenna in X-band [9] is taken. Antenna is resonating in X-band with measured gain is varied from 3-5dB throughout frequency band. FSS is used as superstrate to this antenna.

Fig. 6 shows the structure of the antenna with 2 layers of FSS. The simulated reflection from this antenna is shown in Fig.7, and it is seen that almost the full X-band is covered by this antenna. The simulated gain enhancement of the antenna is shown in Fig.8 and it is observed that significant gain enhancement is achieved in only a small band.

Initial experiments involved measuring the S21 between two such antennas, with FSS superstrate for one, as shown in Fig.9. The measured S21 is shown in Fig.10, and unfortunately gain enhancement is not observed. Efforts are on to resolve the discrepancy between simulation and measurement, and to improve the bandwidth for gain-enhancement (at least 10-12 GHz should be achieved as indicated by Fig.5).

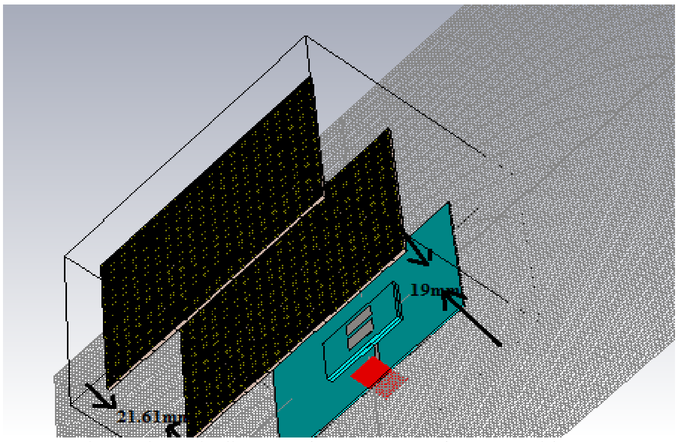

Fig.6 Schematic diagram of arrangement of antenna with FSS

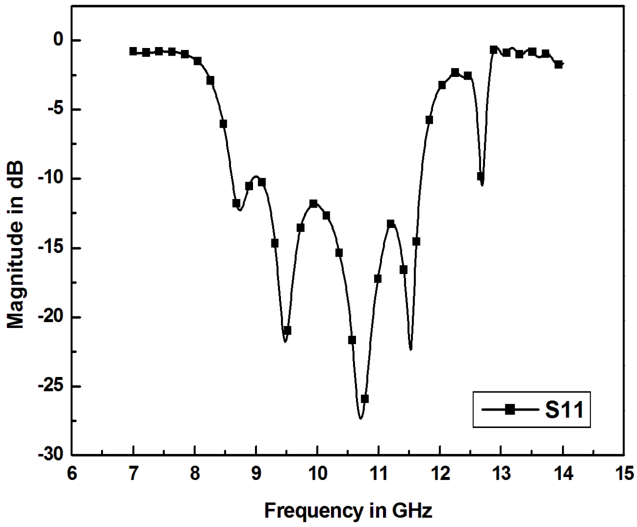

Fig.7 Simulated result of S11 with antenna and FSS

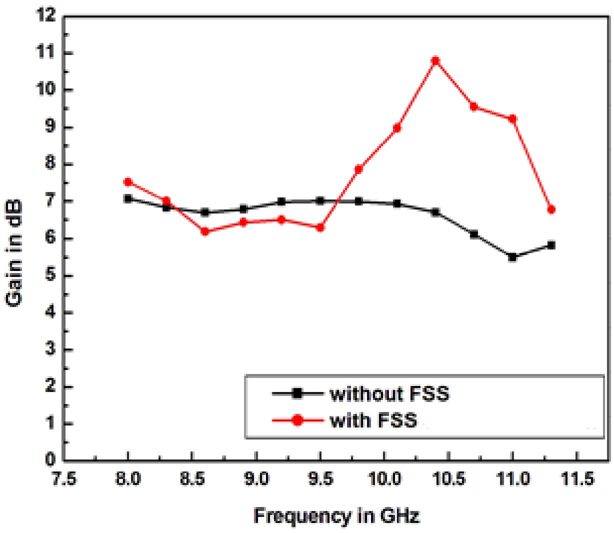

Fig 8. Simulated Gain comparison of antenna with and without double layer FSS


Fig.9 Measurement setup for S21 of stacked antenna with double layer FSS

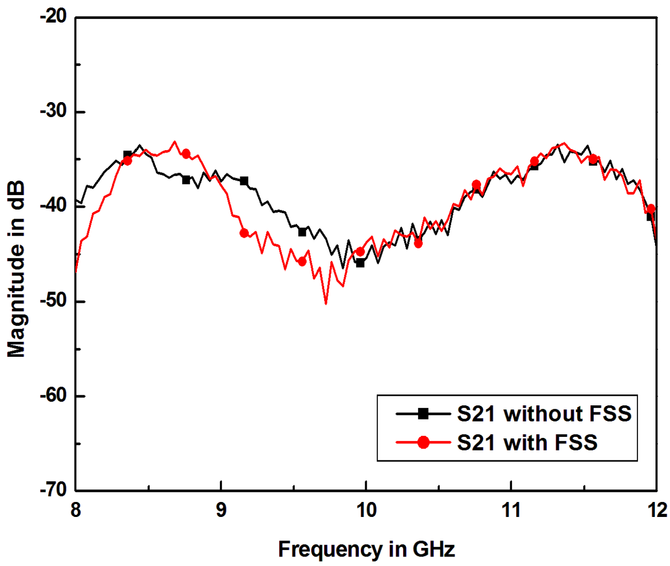

Fig.10 Measured result of S21 with double layer FSS and stacked antenna

IV. CONCLUSION

Multilayer FSS for antenna gain enhancement is studied. Using multilayer structure potential gain enhancement of a broadband printed antenna is demonstrated.

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