Active Frequency Selective Surface Using PIN Diodes

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A novel active frequency selective surface (FSS) is presented for 2.45 GHz applications. It consists of circular aperture elements with four PIN diodes placed orthogonal to each other on FR4 substrate. The negative dc biasing is provided with cross shaped supply lines from the reverse side of the substrate, while positive biasing is provided from the front side of printed circular structure. This active FSS design enables transmission to be switched on or off at 2.45 GHz, providing high transmission when the diodes are in OFF state, and high isolation when the diodes are ON. The design also provides very good stability to oblique TE incidence, i.e perpendicular polarisation. Preliminary theoretical results are described.

Introduction

Active frequency selective surfaces (FSS) have been used as spatial filters for microwave frequencies for several decades [1]. In most designs, achieving oblique angle stability for different polarisations is a real challenge. Since FSS is a spatial filter and the electromagnetic wave impinging on its surface may strike from different angles, the impedance of FSS surface changes due to the resolution of E vector into its tangential and normal components and hence the frequency response. In this paper an active FSS has been presented for 2.45 GHz that shows a stable frequency response at oblique TE incidence, i.e perpendicular polarisation. Four PIN diodes have been used in a unit cell to switch the FSS ON and OFF in the required band. In the ON state, each unit cell is shorted resulting in a conducting plane that reflects power impinging on it. On the other hand when the diodes are in the OFF state, the FSS behaves as a band pass filter for 2.45 GHz. Circular unit cells have been used in the FSS design due to their stable performance for oblique angles [2]. Further stability has been achieved by decreasing the inter-elements spacing of the FSS apertures and employing symmetrical DC bias lines [2].

The Design

The dimensions and layouts of a unit cell of the active FSS are depicted in Fig. 1 . The active FSS layer is printed on a 420×270 mm FR4 sheet with dielectric constant of 4.4. The bandpass characteristics are achieved by incorporating an array of circular apertures on one side of the FR4 sheet, which has a thickness of 1.6 mm. The dimensions of the circular aperture is selected in such a way that its resonance without PIN diodes is higher than 2.45 GHz. This is due to the fact that after incorporating PIN diodes in the model, an appreciable inductance and capacitance

1-4244-0878-4/07/$20.00 ©2007 IEEE

is added to the design and hence the resonance frequency is shifted towards the lower side of frequency band.

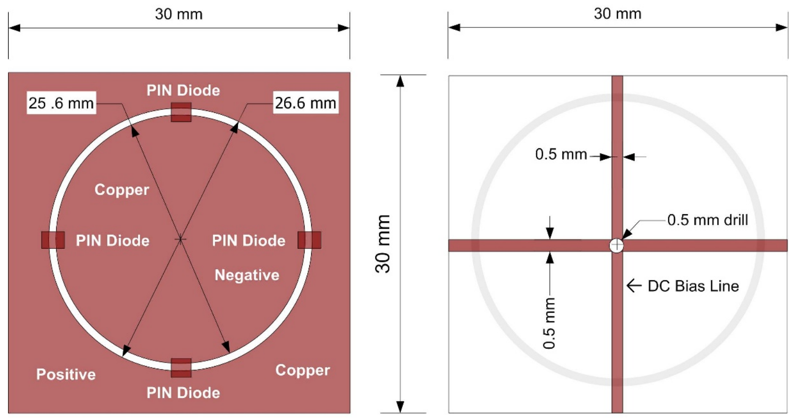

Figure 1: The layout of a unit cell. Left: front side, Right: reverse side.

The width of the annular aperture is 0.5 mm. Cross shaped symmetrical negative dc bias lines are employed on the reverse side of the dielectric substrate while positive dc biasing is achieved from the printed side of FSS structure. The width of the cross shaped bias lines is 0.5 mm. A 0.5 mm hole is drilled through the center of each cross shaped bias line to the center of circle on the other side of substrate and an electrical connection is made by connecting a 0.5 mm pin through the hole. The width and symmetry of the bias lines, the size of connecting pin and the closely packed FSS circular elements have been employed to achieve a stable transmission response for perpendicular polarisation, i.e TE oblique incidence.

PIN Diode

Fig. 2 shows a PIN diode along with its equivalent circuit models in forward and reverse bias modes. Fig. 2(a) shows the cross section of the PIN diode while Fig. 2 (b) and (c) depict the forward and reverse bias equivalent circuits. For the convenience of theoretical modeling, the reverse bias equivalent circuit of the PIN diode has been converted into a series RLC circuit model as depicted in Fig. 2 (d). The RLC series lumped element in CST Microwave Studio has been used in modeling the active FSS unit cell. The typical values used for forward bias are $R = 5\ \Omega$ and $L = 0.4\ nH$, while for reverse bias a series capacitance of 0.27 pF has been added to the circuit model.

Results

Fig. 3 depicts the results of the simulation showing the transmission and reflection characteristics of the active FSS at 0, 30 and 45 degree incident angles for perpendicular polarisation (TE) when the PIN diodes are in OFF state.

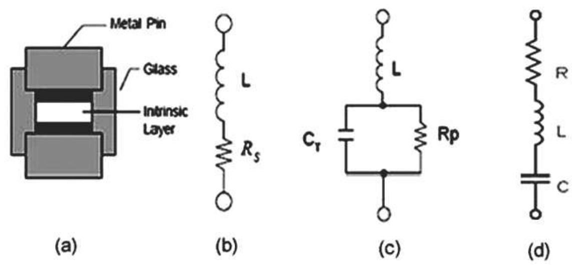

Figure 2: The PIN diode (a) cross section, (b) the forward bias equivalent circuit, (c) the reverse bias equivalent circuit and the (d) the equivalent RLC series circuit model for reverse bias.

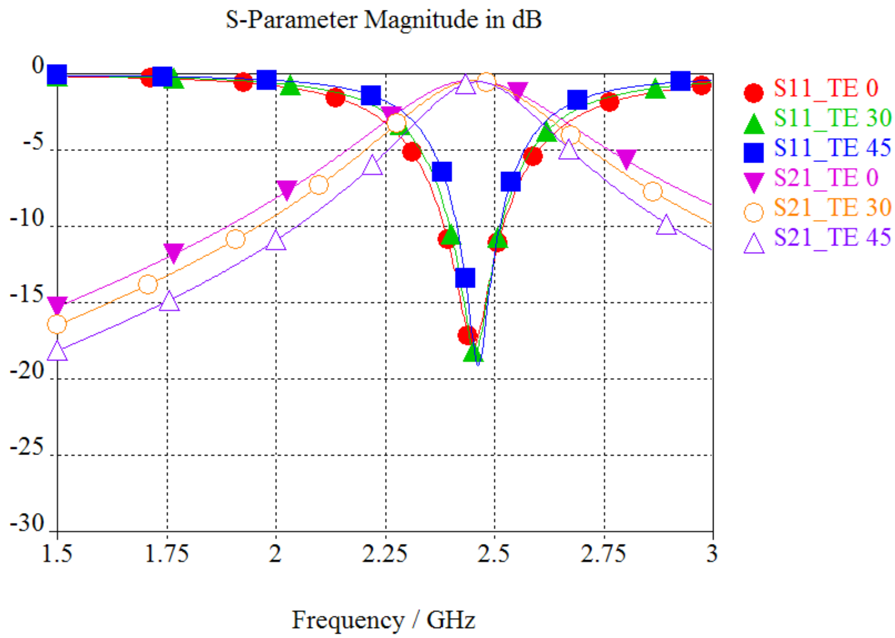

Figure 3: The transmission and reflection characteristics of the active FSS for oblique angles when the PIN diodes are in OFF state.

The reflection coefficient $|S_{11}|$ at 0, 30 and 45 degrees is -17.9, -18.4 and -19.1 dB respectively. The -5 dB bandwidth at 0 degree is 293 MHz, at 30 degree 252 MHz while at 45 degrees it's 206 MHz. There is a reduction in bandwidth for high angle of incidence. As far as the transmission is concerned, a small insertion loss of 0.35 dB can be noticed for all incident angles considered. This is due to the loss in PIN diodes.

Both transmission and reflection characteristics of the active FSS in ON state are presented in Fig. 4. When the diodes are ON, all the circular apertures are shorted together, effectively resulting in a plane conducting sheet. There is no considerable change in the reflection properties as the angle of incidence increases from 0 to 45 degrees while the transmission coefficient vary from -17.8 dB to -20.1 dB for 2.45GHz. Therefore when the diodes are ON, the active FSS provides very good isolation. It may be used to isolate, when required, two concurrent WLANs, with

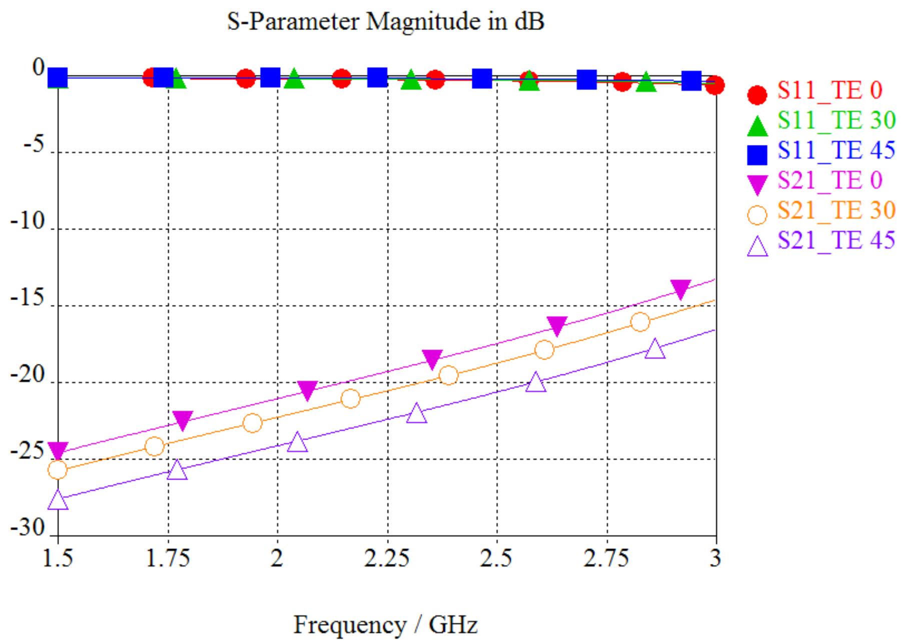

Figure 4: The transmission and reflection characteristics of the active FSS for oblique incidence when the PIN diodes are in ON state.

dynamic ON and OFF provision.

Conclusion

An active FSS with circular aperture periodic structures and PIN diodes has been investigated. Our design has shown stable transmission response at oblique TE incidence, i.e perpendicular polarisation in both ON and OFF states. This change in response is electronically controlled. There is a small insertion loss due to PIN diodes in OFF state and the design has shown a good isolation between transmission and reflection. Beside other applications, it may be used to isolate concurrent WLANs from each other to avoid interference and signal degradation.

Acknowledgement

We would like to thank Professor Richard Langley, Head of communications group, University of Sheffield, for his moral, technical and administrative support during the course of this project.

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