Performance Evaluation of Annular Ring Frequency Selective Surface for Different Substrate Materials

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Abstract: **In recent years, the study of newer types of dielectric materials and Frequency Selective Surfaces (FSSs) have been the subject of intensive investigations. The quest for new, innovative and easily obtainable dielectric materials with FSS in annular form that yield predictable and controllable S parameter with sharp cutoff has always been fruitful. New ideas and designs to implement these materials i.e. Teflon, Mica and FR4 with annular structures will be simulated at microwave frequencies over various bands to observe the performance. In this paper authors represent the effect of change in dielectric constant with respect to shift in operating resonance frequency .The results will be tabulated to show dual band cutoffs with different dielectrics.**

Keywords: FSS, Annular ring, dielectric constant, Dielectric Substrate

I. INTRODUCTION

A dielectric is an electrical insulator that can be polarized by an applied electric field. When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in a conductor, but only slightly shift from their average equilibrium positions causing dielectric polarization. A dielectric is typically used to describe materials with a high polarizability. It is expressed by a number, which is called the dielectric constant. A common example of a dielectric is the electrically insulating material between the metallic plates of a capacitor. The polarization of the dielectric by the applied electric field increases the capacitor's surface charge some dielectrics used during designing FSS are: FR-4 (lossy), Mica and Teflon In This Research work we use FR-4 (lossy) Mica and Teflon material as dielectric substrates. The metallic patch that is deposited over the dielectric substrate acts as a conducting element. It is responsible for producing dual band dips at specific frequencies in C and X band.

II. MICROWAVE PROPERTIES OF DIELECTRIC MATERIALS

The ideal dielectric does not exhibit electrical conductivity when an electric field is applied. In practice, all dielectrics do have some conductivity, which generally increases with increase in temperature and applied field. If the applied field is increased to some critical magnitude, the material abruptly becomes conducting, a large current flows and local destruction occurs to an extent dependent upon the amount of energy which the source supplies to the low conductivity path. This critical field depends on the geometry of the specimen, the shape and material of the electrodes, the nature of the medium surrounding the dielectric, the time variation of the applied field, and other factors. Temperature instability can occur because of the heat generated through conductivity or dielectric losses, causing thermal breakdown. Breakdown can be brought about by a variety of different causes, sometimes by a number of them acting simultaneously. Dielectric strength is measured through the thickness of the material (taking care to avoid surface effects) and is normally expressed as a voltage gradient (volts per unit length). As well as dielectrics breaking down, as described above, most capacitors lose a fraction of the energy when an alternating current is applied. In other words, the dielectric is less than perfect.[8][5]

As frequencies increase, the amount of signal loss into the substrate becomes more significant. As a result, the choice of substrate material becomes more important to the success of the design. When examining material types, the polymer and the substrate each has a major influence on the electrical characteristics of the laminate materials.[8]

a) Teflon/ PTFE(Poly tetra fluoro ethylene)-

Its four great properties are: 1. very low coefficient of friction, 2. highly inert, 3. high melting point, 4. wonderful electrical properties. These properties are due to its unique molecular structure PTFE's mechanical properties are low compared to other plastics, but its properties remain at a useful level over a wide temperature range of -100°F to +400°F (-73°C to 204°C). Mechanical properties are often enhanced by adding fillers (see paragraph below). It has excellent thermal and electrical insulation properties and a low coefficient of friction.[5]

b) *Mica-*

Mica has the unique combination of great dielectric strength, uniform dielectric constant and capacitance stability, low power loss (high Q factor), high electrical resistivity and low temperature co-efficient and capacitance.

Mica is fireproof, infusible, incombustible and non-flammable and can resist temperatures of 600° C to 900° C (1112° F to 1652° F) depending on the type of mica. It has low heat conductivity, excellent thermal stability and may be exposed to high temperatures without noticeable effect.[5]

c) *FR4-*

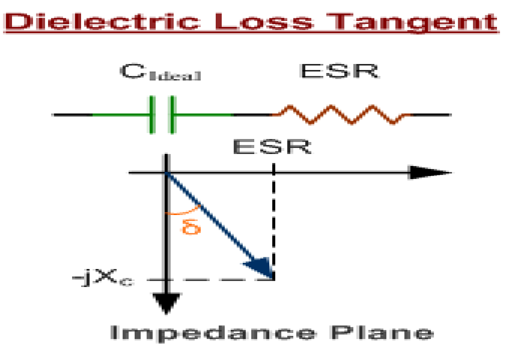
"FR" stands for flame retardant, and denotes that safety of flammability of FR-4he material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. These attributes, along with good fabrication characteristics, lend utility to this grade for a wide variety of electrical and mechanical applications.

Table1 Dielectric Property of Substrate

Dielectric Material	Dielectric Constant	Dielectric Strength MV/m	Tangent Losses
Teflon	2.1	118	.001
Mica	6	250	0.014
FR4	4.7	20	0.021

The dielectric loss tangent is defined by the angle between the capacitor's impedance vector and the negative reactive axis, as illustrated in the diagram to the right. It determines the lossiness of the medium. Similar to dielectric constant, low loss tangents result in a "fast" substrate while large loss tangents result in a "slow" substrate.

The dielectric constant can be calculated using: $\varepsilon = Cs/Cv$, where Cs is the capacitance with the specimen as the dielectric, and Cv is the capacitance with a vacuum as the dielectric.[5]



III. DESIGN PARAMETER OF ANNULAR RING FREQUENCY SELECTIVE SURFACE

FSSs are traditionally designed based on the resonant elements. A planar array of strip dipoles for example, produces a frequency response consisting of multiple notches at frequencies where the length of the dipoles is a multiple of half a wavelength. [1]

The idea is that a plane-wave illuminates an array of metallic elements, thus exciting electric current on the elements. The amplitude of the generated current depends on the strength of the coupling of energy between the wave and the elements. The coupling reaches its highest level at the fundamental frequency where the length of elements is a λ/2.[6] As a result, the elements are shaped so that they are resonant near the frequency of operation. Depending on design, the current itself acts as an electromagnetic source, thus producing a scattered field. The scattered field added to the incident field constitutes the total field in the space surrounding the FSS. By controlling the scattered field (designing elements), the required filter response is produced which can be seen in the spectrum of the total field. As mentioned above, the distribution of the current on the elements determines the frequency behavior of the FSS. The current itself depends on the shape of the elements.[5]

The current itself depends on the shape of the elements. A similar effect can explain the operation of other elements. The square loop element for example, can be imagined as two dipoles that are connected to one another at each end. Using the same argument as that of the dipole, a loop resonates when the length of the two sides equals the length of a resonant dipole, λ/2. In other words each side of the loop is about λ/4.

Thus the shape of the elements has the utmost importance effect in the frequency response, the way these elements are arranged in the array format is also part of the design work. Moreover, the response also depends on the characteristics of the substrate used. By thinning and contracting the unit cell, capacitive junctions in the form of shunt or series capacitors are achieved. Inductive traces are also held very close to one another to produce a larger inductive effect as a result of mutual magnetic coupling.[5] In this paper we design two concentric rings with two circular slot in a cell of the FSS. The Cell is embedded in a square patch of size 12mm X 12mm.[1] A single cell is shown in Figure3. A special feature of design is the center position of the unit cell is hollow. That means at center of the rings there is not any kind of metallic layer, so current distribution at center is zero. Which results an Inductive junction in shunt with capacitive junction.

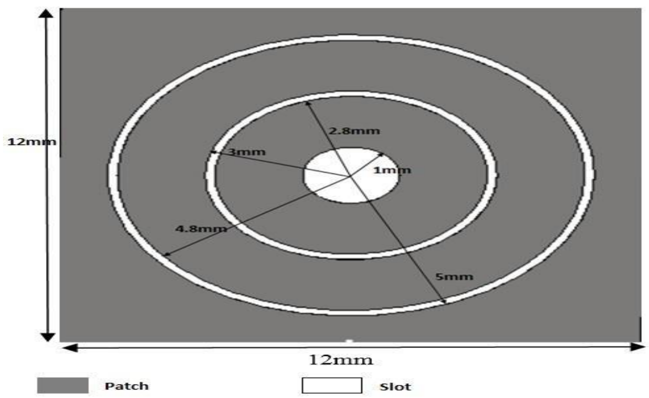


Figure 1. Single Cell of Annular ring FSS

Figure 2. Schematic of side view of proposed FSS structure

Table 2. Design Parameter for Single Cell of Annular Ring Frequency Selective Surface

Square Patch Length {L}	12mm
Square Patch Width {W}	12mm
Ring 1 Inner Radius{r1}	1mm
Ring 1 Outer Radius{r2}	2.8mm
Ring 2 Inner Radius{r3}	3mm
Ring 2 Outer Radius{r4}	4.8mm
Width of Dielectric{Wd}	1.56mm
Width of Conductor{Wc}	0.03mm

IV. SIMULATION OF ANNULAR RING FREQUENCY SELECTIVE SURFACE:

The above mentioned geometry was generated in EM software as a periodic array and simulated for S parameters as shown in figure 3.

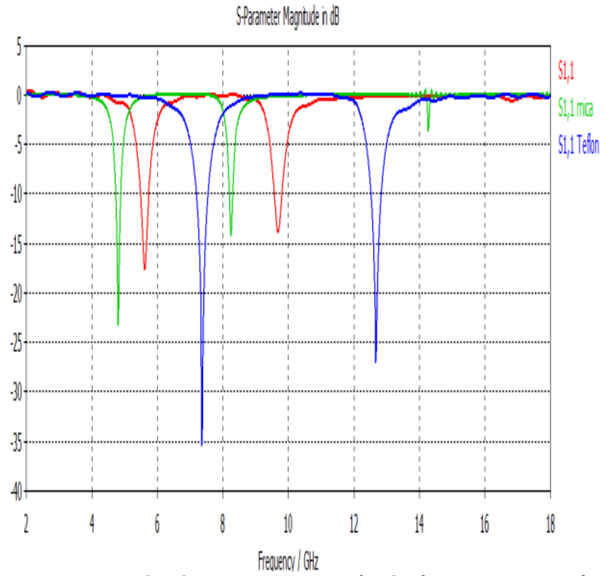


Figure 3. Simulated S-Parameter curve for the frequency sweep of 2 to 18GHz

Figure 4 & 5 shows the effect of substrate material on the behavior of FSS. The results are tabulated in Table 3

The table 3 clearly shows the shift in frequency bands and its dependency on the properties of the base material (substrate)

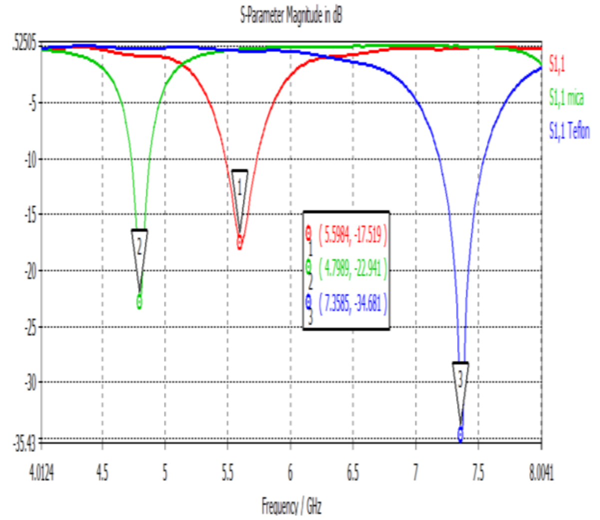


Figure 4.Frequency response of FSS for different Substrate Material in C band

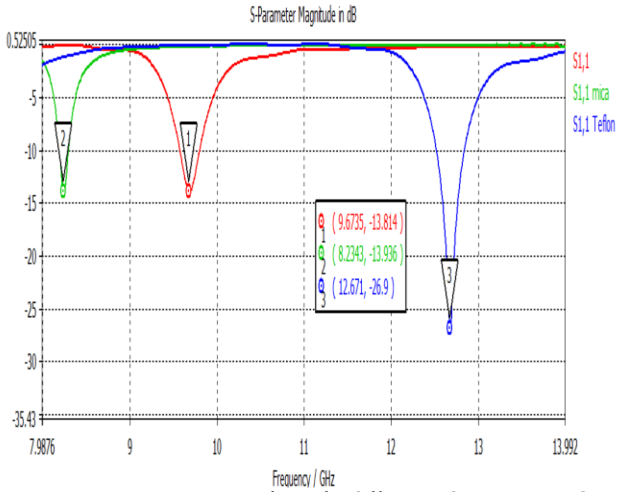


Figure 5. Frequency response of FSS for different Substrate Material in X band

Table 3 Frequency response of FSS at different Substrate Material

Dielectric Material	C Band Frequency	X Band Frequency
Teflon	7.35GHz	12.66GHz
Mica	4.79 GHz	8.22 GHz
FR4	5.58 GHz	9.64 GHz

V CONCLUSIONS

Specific characteristics that have been focused in this work are: the dependence of the frequency-selective surface on the incidence angle of the exciting wave, shapes of metallic patches or slots, the dimensions of the periodic elements, dielectric substrate used and the lattice structure.

The spacing between two rings can be used to control the separation between the cascaded FSS bands. With the variation of Space between inner rings we can shift the resonance frequency in higher band of interest (X-band) whereas by varying Space between outer rings we can shift the resonance frequency in lower band of interest (C-band). Similarly if we change the characteristic property of the substrate i.e Mica Teflon and FR4 the shifting is also changing Fig.no5illutrate these results.

Simulation results were presented for dual-band FSS with different dielectric materials and tabulated in Table no.3

It is observed that the use of annular ring FSS of simple conducting element on various dielectric materials can be used to obtain dual-band response with appreciable shift in frequency

VI. FUTURE SCOPE

Presently, frequency selective surfaces are in use have single base conducting surface i.e copper were observed with different dielectric material. If we observe the table no.2 then we can observe a band ratio equal to 1.7(Approx.) which proves the linear relationship between shift bands Further we can observe the different surfaces other than copper and obtain a linearity relationship of band shifts with base material.

VII. ACKNOWLEDGMENT

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