Global Journals

Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 4 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Parametric Analysis of Tunable Multi Layer Multi Dielectric-High Impedance Surface Reflector

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GJRE-F Classification : FOR Code: 090699

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Abstract- A novel Tunable Multi Layer Multi Dielectric High Impedance Surface (TMMD-HIS) Reflector is proposed and designed in Ansoft HFSS software. The structure of TMMD-HIS consists of square metal patch arrays arranged in three dimensional, connecting vias, dielectric substrates arranged in ascending order. It exhibits two important properties first one barrier to EM waves in certain band of frequencies. Second it reflects the waves with a co-efficient of +1. Some important parameters of TMMD-HIS reflectors architecture and its effect on reflection phase characteristics, operating frequency and band width is investigated and results are presented.

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I. Introduction

In present communication systems the engineered electromagnetic structures occupying important role because of its interesting characteristics the tunable Multi Layer Multi Dielectric High Impedance Surface Reflector proposal is an engineered EM structure exhibits high surface impedances for both transverse electric (TE) and transverse magnetic (TM) polarisations and can suppress surface wave propagation at certain frequency ranges. Furthermore, the surface wave band gap property of Multi Layer Multi Dielectric High Impedance Surface helps to increase the antenna band width, minimize backward radiation, and reduce mutual coupling. In phase reflection between incident and ground reflected waves, this resembles the property like PMC (Perfect Magnetic Conductor). Hence, they can play an important role in developments of new applications in wireless radio communications, antenna engineering and beam steering.

II. Unit Cel Meodeling

The structure of Multi Layer Multi Dielectric High Impedance Surface consists of an optically planar ground plane, dielectric substrates arranged in ascending order, square metal patches (protrusions) arranged in three dimensionally and metal vias joining the metal protrusions to ground. The arrangement is shown in figure 1.

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The unit cell has following dimensions; thickness of lower substrate t =62mil with a relative permittivity of εr =2.2 and loss tangent 0.0009, diameter of via d =0.65mm, width of patch w = 41mm, gap g = 2.5mm, hidden layer patch width Hw = 46mm height of TMMD-HIS h = 3mm and an air is considered as another dielectric exist between top and bottom layers. This structure resonates at 1.89GHz.

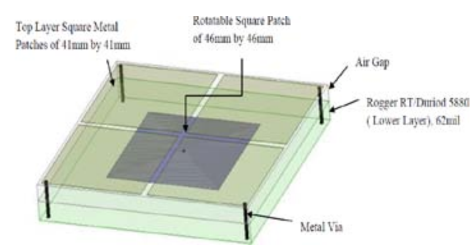

Fig. 1 : Description of structural parts unit cell.

III. Reflection Phase Measurement

A proposed unit cell is designed and executed in Ansoft HFSS software. By placing in a box to which a periodic boundaries are applied and extended to infinity. Finite Element Method is adopted to analyze the proposed unit cell.

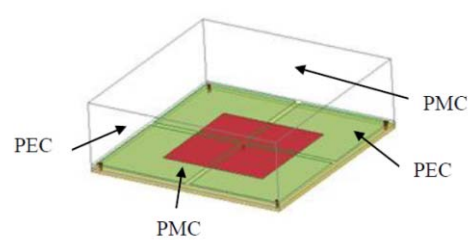

Fig. 2 : Reflection Phase Measurement Setup.

The diagrams in figure 2 is showing perfect electric boundary at opposite walls of unit cell box, and perfect magnetic boundary at opposite walls of remaining unit cell box. The figure 3 is showing the reflection phase of normally incident plane wave on TMMD-HIS structure versus frequency. At low frequencies this structure reflects with a $+180^0$ phase shift as the frequency increases the phase slops downward and crosses through zero degree point and reaches to -180^0 the frequency at this phase is high. The point of intersection of the phase curve with zero degree

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line, frequency at this point is considered as operating frequency. The region between +87.92 degree to –176.08 degree shown in Figure3 with highlighted region reflects the plane waves in phase with transmitted wave. This region functions like Perfect Magnetic Conductor (PMC). This range corresponds to surface wave band gap. The region before and after to highlighted region functions like ordinary reflector.

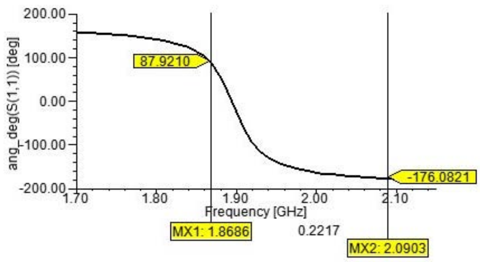

Fig. 3 : Reflection Phase

IV. Parametric Study of TMMD- his Reflector

It has investigated and observed that the input match frequency band of TMMD-HIS reflector has a range starts from +87.92 degree to –176.08 degree shown in Figure3. The reflection phase is mainly depends on following parameters. Top layer patch width (W), gap width (g), height of structure (h), thickness of lower substrate (t), hidden layer patch width (Wh). This analysis may give design guidelines to engineered electromagnetic structures. A finite element method is used to analyse, by taking complete electrodynamics of TMMD-HIS reflector in account. The input match frequency band in this section refers to surface wave band gap.

a) *Patch Width Effect (W)*

Patch width plays an important role in determining the frequency band. To study the effect of patch width, all other parameters are kept in its specified size as explained in unit cell design. The patch width is varied from 32mm to 54mm Figure 4 is showing the reflection phases of normally incident plane waves by the TMMD-HIS reflector at different width values of patch. Table I showing the operating frequency and band width at different values of patch widths. In two dimensional EBG structures consists of an array of patches backed by some dielectric substrate and are connected to ground reflector with via. This two dimensional structure is effected by some parameters like width of patch, gap width, height, substrate permittivity. Results given in many papers [--]. For the first time TMMD-HIS is a three dimensional structure, this novel structure is allowing to change its surface impedance by physically varying the capacitive reactance in the structure. when patch width increases the operating frequency is falling down and band width is increases, from table I it is clearly showing that, when patch width value is at 32mm the operating frequency is 2.0467GHz and band width is 172.9MHz as the patch width progresses and reaches to 54mm the operating frequency falls down to 1.6976GHz and band width increases to 214.4MHz. The figure 5 and 6 are clearly showing the effect of patch width and corresponding variation of operating frequency and band gap.

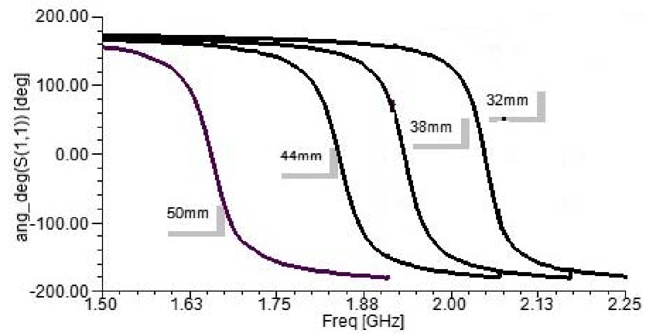

Fig. 4 : Reflection Phase of patch widths at 32mm, 38mm, 44mm, 50mm

Table I : Patch Width Effect

Width (mm)	Operating Frequency (GHz)	Upper Frequency (GHz)	Lower Frequency (GHz)	Band Width (MHz)
32	2.0467	2.1981	2.0252	172.9
34	2.0252	2.18	2.0022	177.8
36	1.9577	2.1109	1.9347	176.2
38	1.933	2.0878	1.9083	179.5
40	1.9067	2.0648	1.8820	182.8
42	1.8820	2.0467	1.854	192.6
44	1.8375	2.0022	1.8112	191.0
46	1.7618	1.9182	1.7355	182.8
48	1.7289	1.8985	1.7025	195.9
50	1.6548	1.8326	1.6284	204.2
52	1.6679	1.8458	1.6383	207.5
54	1.6976	1.8771	1.6630	214.1

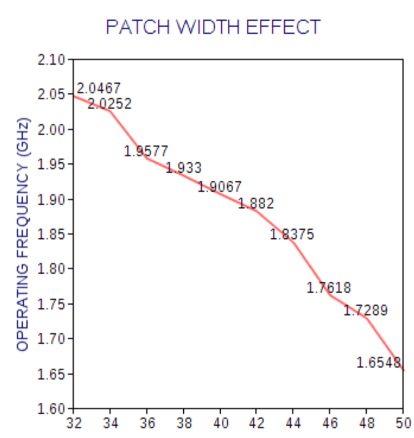

Fig. 5 : Patch width effect on operating frequency

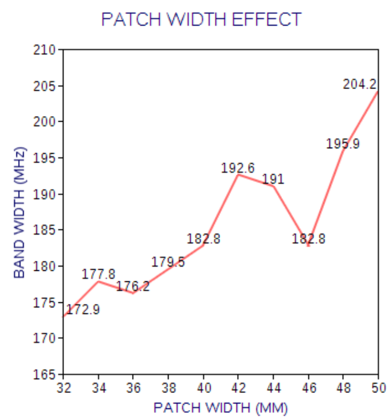

Fig. 6 : Patch width effect on Band width

b) Gap Width Effect (g)

The gap width is the distance between adjacent patches, where the small amount of capacitance is developed due to fringing fields between the patches. In the proposed work it controls the coupling between patches of TMMD-HIS. To understand the effect of the gap width on the structure the gap width is varied from 1.5mm to 3.5mm. During this investigation all other parameters are kept in its specified size as explained in unit cell design. The operating frequency and band width are the parameters to visualize the effect. Figure 6 is showing the reflection phase characteristics of the proposed structure when gap width is varied for normal incident plane waves. Represents variation of operating frequency due to gap width. Table II showing how the operating frequency and band width for different gap width values. As you observe the progress in gap width there is demolish in both the operating frequency and band width. When gap width is at 1.5mm the operating frequency is 1.9042mm and band width is 219.8MHz respectively as the band width reaches to 3.5mm both operating frequency and band width falls down to 1.8919GHz and 174.5MHz respectively. This is clearly visualized in figure 7 and 8.

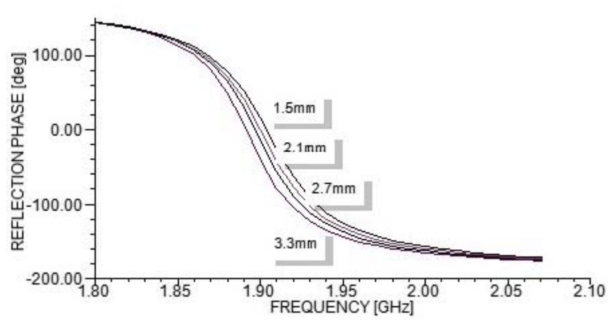

Fig. 6 : Reflection Phase of gap width at 1.5mm, 2.1mm,2.7mm,3.3mm

Table 2 : Gap Width Effect

Gap (mm)	Operating Frequency (GHz)	Upper Frequency (GHz)	Lower Frequency (GHz)	Band Width (MHz)
1.5	1.9042	2.0952	1.8754	219.8
1.7	1.9042	2.0804	1.8754	205.0
1.9	1.9009	2.0730	1.8729	200.1
2.1	1.9001	2.0689	1.8729	195.9
2.3	1.9001	2.0656	1.8729	192.6
2.5	1.8952	2.0574	1.8688	188.5
2.7	1.8968	2.0574	1.8713	186.1
2.9	1.8952	2.0524	1.8696	182.8
3.1	1.8927	2.0475	1.8680	179.5
3.3	1.8919	2.0450	1.8664	178.6
3.5	1.8919	2.0417	1.8664	175.4

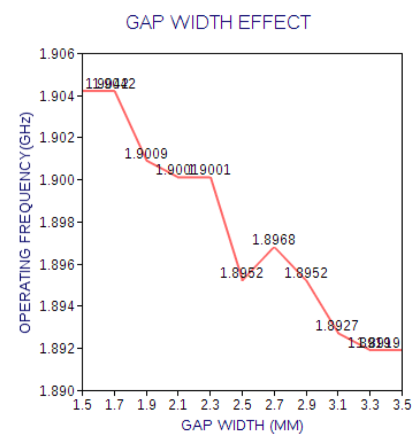

Fig. 8 : Gap width effect on operating frequency

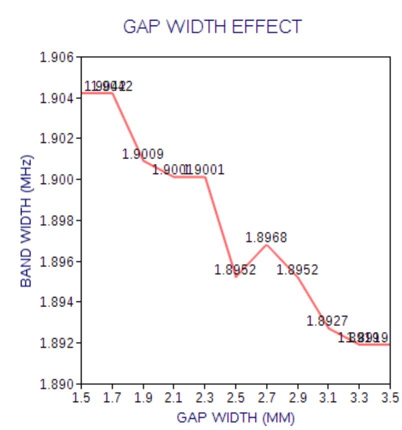

Fig. 9 : Gap width effect on band width

c) Height of Structure (H)

In Tunable Multi Layer Multi Dielectric High Impedance Surface total height of structure is considered from lower substrate bottom face contains optically planar conducting surface to higher substrate bottom face containing array of square patches of fixed structure. The total height of a structure here is the sand which of Rogger/RT Duriod 5880 and air substrates. In this case of investigation all other parameters are kept in

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its specified size as explained in unit cell design. Since we are considering thickness of Rogger/RT Duriod is at fixed value of 62mil and varying the height will indirectly vary the air gap causes the reactive capacitance developed in this air gap going to be change. In two dimensional structures as you vary the height of structure the operating frequency is giving to vary inversely with respect its height and band width has linear relation. In TMMD-HIS is giving liner results in both operating frequency and band gap. Table 3 is showing the simulated results, clearly showing that as the positive progress in the height of structure The operating frequency, band width are increasing. When height is at 2mm the operating frequency is 1.6805GHz and band width is 167.3MHz, when height is reaches to 3mm the operating and band width reaches to 1.8952GHz and 189MHz. This is clearly visualized in figure 11. figure 12.

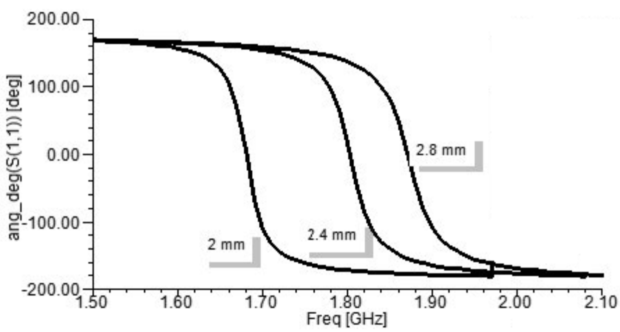

Fig. 10 : reflection at different h values

Table 3 : Effect of structure height

Height (mm)	Operating Frequency (GHz)	Upper Frequency (GHz)	Lower Frequency (GHz)	Band Width (MHz)
2	1.6805	1.8333	1.6660	167.3
2.2	1.7523	1.9031	1.7345	168.6
2.4	1.8030	1.9610	1.7825	178.5
2.6	1.8431	2.0052	1.8207	184.4
2.8	1.8701	2.0322	1.8458	186.4
3	1.8952	2.0578	1.8688	189.0

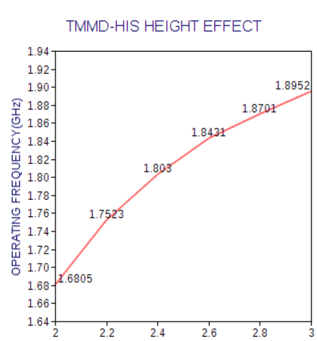

Fig. 11 : height effect on operating frequency

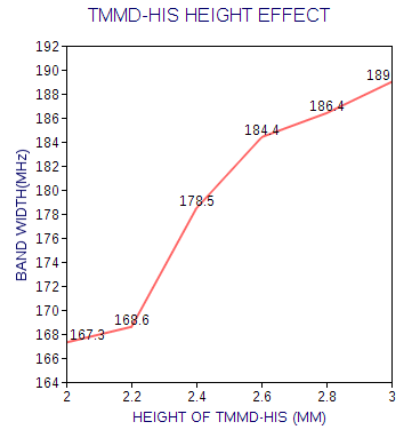

Fig. 12 : height effect on band width

d) Thickness of Lower Substrate (t)

Lower substrate thickness is another parameter effect when there is changes in its structure. the structural variation may present in mode, here we considered only thickness is varied from 55mil to 65mil by considering remaining all other parameters are kept in its specified size as explained in unit cell design. The variation in lower substrate thickness alters the air gap height since total structure height is considered constant. The simulated results obtained are presented in table 4. When thickness is at 55mil operating frequency is at 1.9268GHz band width is at 179.1. Thickness is next raised to 65mil the operating is moved down to 1.8794GHz and band width raised to 195.6MHz. This is visually presented in figure 14 and 15. figure 13 is showing the reflection phase characteristics of plane when normally incident the surface when thickness is at 55mil, 59mil, 62mil, 66mil.

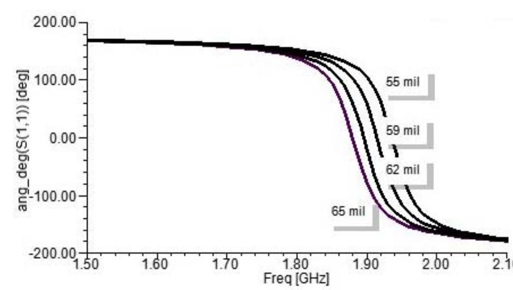

Fig. 13 : Reflection phase characteristics at different thickness values of lower substrate

Table 4 : Thickness of Lower Substrate effect

Thickness (mil)	Operating Frequency (GHz)	Upper Frequency (GHz)	Lower Frequency (GHz)	Band Width (MHz)
57	1.9268	2.0828	1.9011	179.1
59	1.9136	2.0717	1.8873	184.4
61	1.9011	2.0618	1.8741	187.7
63	1.8925	2.0578	1.8655	192.3
65	1.8794	2.0486	1.8530	195.6

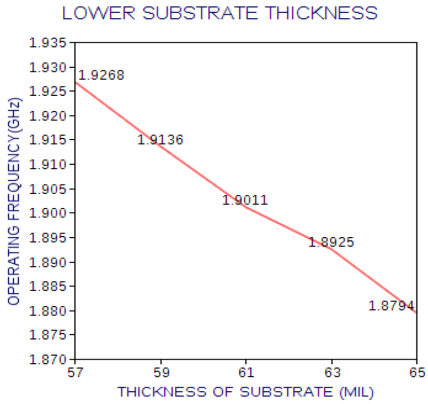

Fig. 14 : effect of substrate thickness on operating frequency

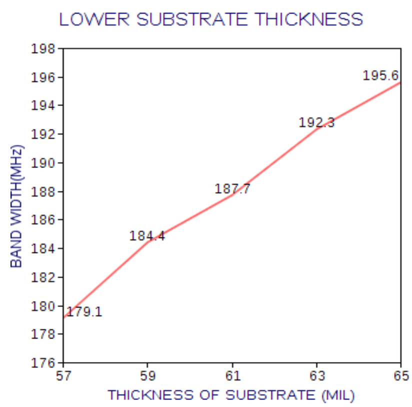

Fig. 15 : effect of substrate thickness of band width

e) Hidden layer Patch Width (revolving Patch)(Wh)

This patch has a very important nature of work i.e revolving around its center axis either in clock or anti clock wise direction with respect to immovable layer of patches lying above to it. When it starts revolving alters the parallel plate capacitance reactance exist. Present analysis to understand its effect only patch width is varied from 40mm to 50mm during this time all other parameters are kept in its specified size as explained in unit cell design. Varying this it's structure means altering the overlapping area between parallel plates result change in capacitive reactance. Table 5 is showing the simulated results explaining that as the patch width increases the operating frequency and band are going demolish. When patch width is at 40mm the operating frequency and band width are at 2.0653GHz and 242.6MHz, when patch width increased to 49mm the operating frequency and band width are reached to 1.8238GHz and 171.2MHz. Figure 17, 18 are visualizing the above statement. Figure 16 is showing the reflection phase characteristics at 40mm, 43mm, 46mm and 49mm values of rotatable patch width.

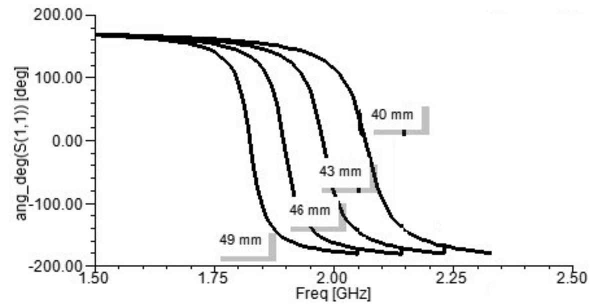

Fig. 16 : Reflection phase characteristics of rotatable patch width

Table 5 : revolving patch width effect

Wh (mm)	Operating Frequency (GHz)	Upper Frequency (GHz)	Lower Frequency (GHz)	Band Width (MHz)
40	2.0653	2.2684	2.0258	242.6
41	2.0335	2.2289	199.73	231.6
42	2.0027	2.1905	1.9676	222.8
43	1.9764	2.1564	1.9435	213.0
44	1.9468	2.1202	1.9160	204.2
45	1.9204	2.0884	1.8919	196.5
46	1.8952	2.0576	1.8677	188.9
47	1.8710	2.0280	1.8447	183.3
48	1.8469	1.995	1.8227	176.7
49	1.8238	1.9720	1.8008	171.2

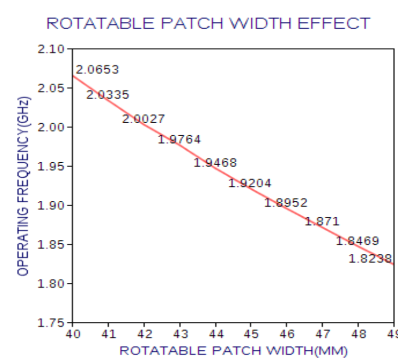

Fig. 17 : effect of rotatable patch width on operating frequency

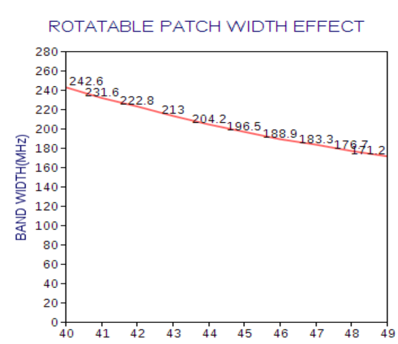

Fig. 18 : effect of rotatable patch width on band width

f) Via Radius

The radius of via is varied from 0.4mm 0.8mm remaining all other parameters are considered are kept in its specified size as explained in unit cell design. It was found that the radius has small effect on the frequency band due to thin via used. Figure 19 is showing the reflection phase at 0.3mm, 0.5mm, 0.7mm, 0.9mm values of via radius. Figure 20,21 are visualizing effect of via radius on operating frequency and band width. The increase in via radius increases the operating frequency and reducing the band width.

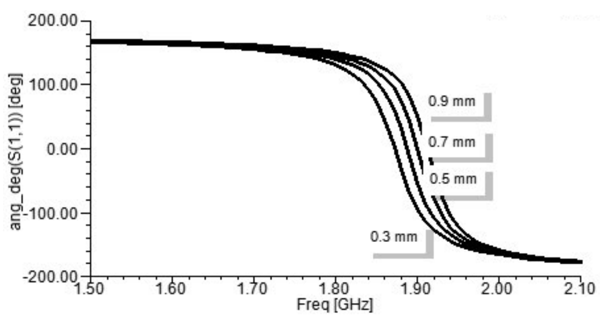

Fig. 19 : Reflection phase curve for different via radius values Table effect of Via Radius

Radius (mm)	Operating Frequency (GHz)	Upper Frequency (GHz)	Lower Frequency (GHz)	Band Width (MHz)
0.3	1.8715	2.0605	1.8425	218.0
0.5	1.8873	2.0572	1.8603	196.9
0.7	1.9	2.0318	1.8741	187.7
0.9	1.9123	2.0671	1.8866	180.5

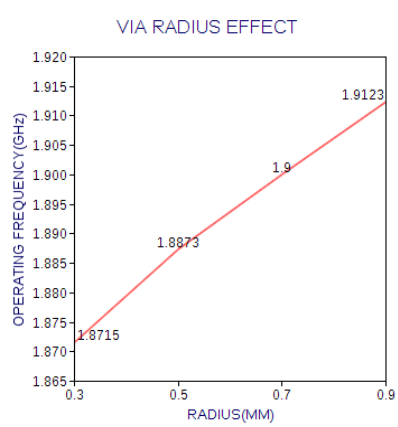

Fig. 20 : effect of via radius on operating frequency

V. Conclusion

A novel Tunable Multi Layer Multi Dielectric High Impedance Surface is proposed. Some of its important parameters and its effect on reflection, operating frequency and band width is studied and presented.

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