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Design of Multilayer High Impedance Surface for Antenna Applications

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Abstract— **In the recent years High Impedance structures are drawing lot of interest in electromagnetic and antenna community. Due to compact sizes of electronic devices, required radiating element to be placed closed vicinity to electronic and biological systems hence designed antenna should have maximum radiated gain, with minimum near filed coupling with environment. This is achievable with periodic electromagnetic structures. By the Engineered electromagnetic surface textures, the properties of the metal surface are altered to perform required functions, such as change of surface impedance, to manipulate the propagation of surface waves or to control the reflection of phase. My present paper concentrating on two dimensional HIS, Multi layered mushroom type metal protrusions. They are analyzed as resonant LC circuits, These materials provide high impedance boundary conditions for both polarizations and for all propagation directions**

Index Terms— **HIS, Surface wave, Rectangular Patch.**

I. INTRODUCTION

In latest Meta-materials there are so many models up to now most of them are single layered structures but here we are considering a two layered HIS and the design is simulated by HFSS these Meta-materials have made improvements in radiation and BW and some other parameters of antennas used in Real time here we further more can develop these parameters by introducing two layered HIS. Basically monopole antenna is widely used in mobile communications here we are applying this structure to improve the gain of the antenna and reduce the return loss with out altering the BW.

II. DESIGN CONSIDERATIONS

A. High Impedance surface

The design of HIS structure consisting of metal patches on one side, connected by metal vias to a solid conducting sheet. One period of HIS structure can be explained equivalent to parallel LC filter. This LC circuit controls the center frequency. By the applied voltage parallel to the surface causes charges to built up on the ends of metal plate. This fringing electric fields between adjacent metal patches resembles capacitance effect. The inductance is proportional to thickness of ground plane

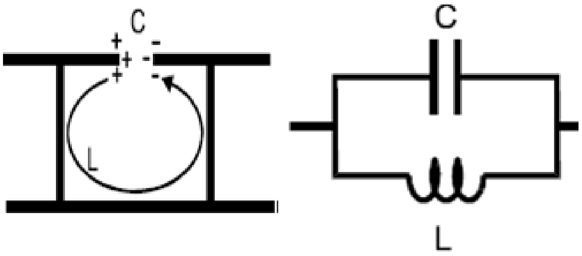

Fig 1: HIS Unit Cell & Its Equivalent

The surface impedance is $Z= JwL/(1-w^2LC)$. Which is inductive at low frequencies, thus supports transverse magnetic waves to propagate. Which is capacitive at high frequencies so it supports transverse electric waves to propagate. When this structure interact with electromagnetic wave, currents are induced in top metal plates and spreads through out the surface such as width of patch, via and ground, develops electric fields at the ends of plates results capacitance, magnetic fields develop current through via and ground plane results inductance. The electric flux developed is

$$\square = (2\varepsilon V/\pi)(\cosh^{-1}[(w+g)/g]).$$

Where w= patch width, g= gap width,

$$C= W\varepsilon_o(1+\varepsilon_r) \cosh^{-1}((2W+g)/g)/\pi$$

sheet inductance is depends on height of substrate and permeability $L=\mu_o\mu_r h$. From the filter theory the resonance frequency of structure is the inverse of square root of the product of inductance and capacitance

$$f= 1/(2\pi\sqrt{LC})$$

High impedance ground planes have mainly two important characteristics 1) this reflects field with zero degree of phase shift at resonance frequency, even when radiating element placed very closed to reflector prepared with same conducting material. the phase of reflection coefficient is +180 degree for low frequencies, then it gradually decreases and becomes 0 degree at resonance frequency and reaches to -180 degree for high frequencies. 2) This provides stop band characteristics for surface wave propagation this improves the antenna radiation pattern hence reduce the multipath and smoothen the radiation pattern.

B. Multilayer High Impedance Surface

The multilayer High Impedance surface consists of dielectric substrate with a ground plane and two arrays of electrically small patches separated with dielectric film and shifted relatively to each other. Here the surface impedance is depends on circuit parameters like capacitance, inductance and equivalent resistance due to dielectric losses.

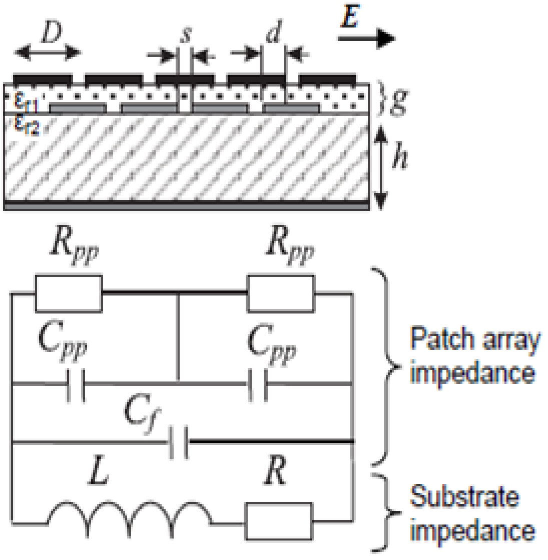

Fig 2: MHIS Unit Cell & Equivalent

The equivalent circuit is obtained by dividing the structure into two parts such as substrate part and patch array part. Analyzing the impedance in this regions we can obtain inductance and capacitance. Representing the ground plane with inductance L and series equivalent resistance R develops due to losses in dielectric. The dielectric substrate with a ground plane is considered as a shorted(Practical line of finite length) transmission line section the input impedance of transmission line at a distance h.

$Z(h)= Z_0[\ Z_L+Z_0\mathrm{Tanh}(\gamma h)]/[\ Z_0+\ Z_L\mathrm{Tanh}(\gamma h)]$

Where

$Z_0 \ = \sqrt{\mu_0 \mu_{r2}} / \varepsilon_0 \varepsilon_{r2}$

Z_0 Is the characteristic impedance of transmission line.

Z_L Is load impedance

$\gamma = Jk_0 \sqrt{\mu_{r2} \varepsilon_{r2}}$ is complex propagation constant

k_0 is wave number,

ε_{r2} relative permittivity,

μ_{r2} relative permeability of substrate medium.

Since load end of transmission line is shorted, the load impedance will be zero. Then the input impedance will be

$Z(h)= Z_0[\ Z_L+Z_0\mathrm{Tanh}(\gamma h)]$

$Z(h)= J\sqrt{\mu_0 \mu_{r2}} / \varepsilon_0 \varepsilon_{r2} \mathrm{Tan}(hK_0 \sqrt{\varepsilon_{r2}})$

Since the distance h is much smaller than the wave length, we will use Tailor series for expansion of tangent. Consider up to third term and neglecting all higher order terms. Grouping real and imaginary parts the substrate input impedance is

$Z(h)=Jk_0\, h[1+ (hK_0)^2 \varepsilon_{r2}/3] + (hK_0)^3 \varepsilon_{r2} \mathrm{Tan}\delta_2\ [\ 1/3+2(hK_0)^2 \varepsilon_{r2}/5]$

This is equivalent to $Z_{substrate}= JwL +R$ after equating real and imaginary parts we get inductance and resistance.
Where $\mathrm{Tan}\delta_2$ is loss tangent of substrate.

The input impedance at two arrays of upper and lower patches is determined by parallel plate capacitance C_{pp} with dielectric losses is determined by $R_{pp.}$

$C_{pp}=(Wd\varepsilon_0\varepsilon_{r1}/g)[1+g/\pi d+g\ln(\pi d/g)/\pi d][1+g/\pi W+g\ln(\pi W/g)/\pi W]$

$$R_{pp}=g/(w\, \varepsilon_0 \varepsilon_{r1} \tan\, \delta_1 A)$$

g is gap between upper and lower patches

A is overlapping area between upper and lower patches
$\mathrm{Tan}\delta_1$ is loss tangent of thin dielectric film between upper and lower patches

The fringing capacitance between lower patches is

$$C_f = W\varepsilon_o(1+\varepsilon_r) \cosh^{-1}((W+g)/g)/\pi$$

total equivalent capacitance of array of patches is

$$C_t=0.5C_{pp}+ C_f$$

Effective impedance of patch array is

$$Z_{patch}=2R_{pp}/(1+2JWC\, R_{pp})$$

Total input impedance of multi layer High Impedance Surface is

$$Z_{MHIS}= Z_{patch}Z_{substrate}/(Z_{patch}+Z_{substrate})$$

For normally incident wave the reflection phase of surface is

$$\Gamma= (Z_{MHIS}-\eta_0)/\ (Z_{MHIS}-\eta_0)$$

The analysis of electromagnetic structure using lumped parameters is valid as long as the wave length is longer than size of individual.

C. *Numerical Design*

Parameter	Value
Patch width	3.5cm
Patch Gap	0.2cm
Sub Height	0.5cm
Reflecting Freq	2.4GHz
Surface Impedance	2.513Ω
Inductance	6.28×10^{-5}H
Capacitance	7×10^{-11} F

III. SOFTWARE DESIGN

Here antenna was designed in Ansoft HFSS software. Ware ground patches width is 3.5cm which are kept at a distance of 0.5cm from planar conducting ground, with a band gap of 2.4GHz. the medium between them is filled with air dielectric with dielectric constant 1.0006.

IV. RESULTS

A. *Return Loss*

This can be defined as ratio of power at receiving end due to incident wave to the power reflected by load. It is the two dimensional curve.

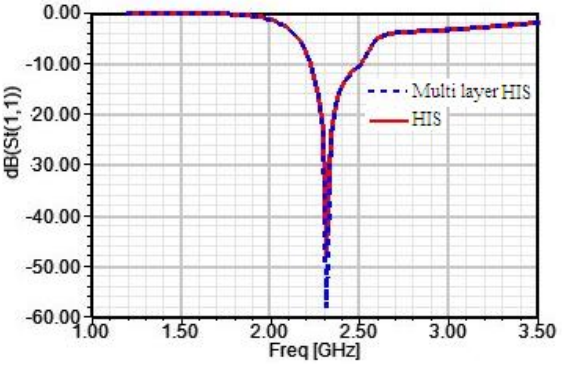

Fig 3: Return loss curve vs frequency

In the above figure it can be seen that the loss is reduced when using the Multi layered HIS in place of single layered HIS. And for both the BW is same.

B. Radiation Pattern

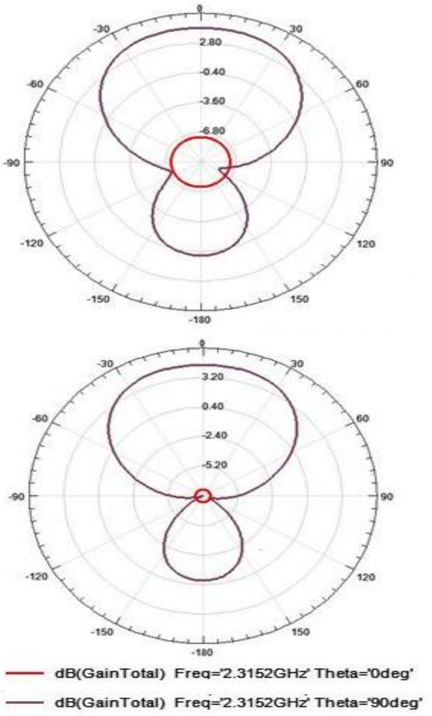

Fig 4: The radiation pattern for Single and Multi layered HIS

In the above figure the radiation is enhanced for multi layered HIS there is no uncovered area at center of the antenna that mean it is radiating with out any uncovered parts near to radiating element.

C. Gain

it is the measure of figure of merit of antenna

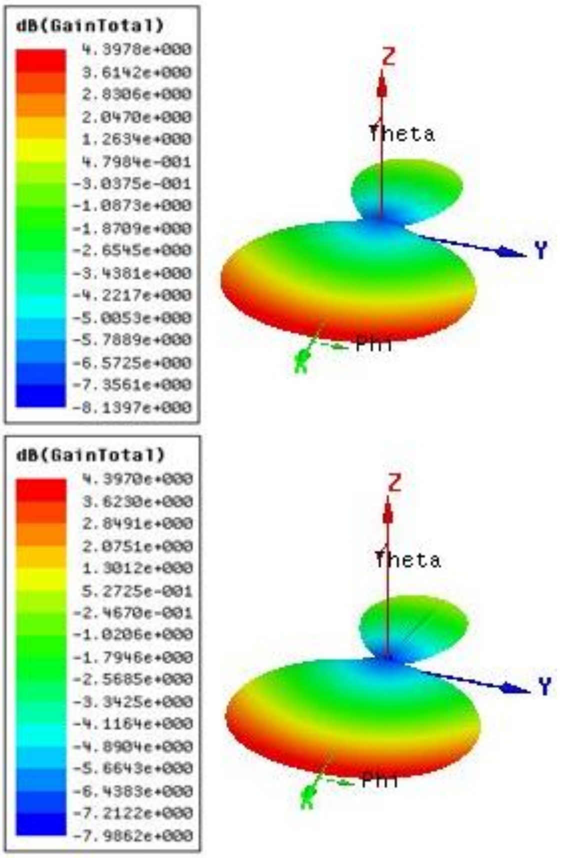

Fig 4: Total Gain in 3D View For Single layer and Multi layered HIS

V. DISCUSSION

By observing the results starting from return loss, radiation pattern, gain, and band width. All the parameters was enhanced in multilayer HIS comparison with normal structure HIS.

VI. CONCLUSION

The use of multi layered structures in place of normal mushroom structure HIS antenna parameters like radiation pattern, return loss were enhanced without altering the BW. Especially when using the HIS there is uncovered area of radiation at center area which is almost covered with radiation when HIS is replaced by multi layers HIS.

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