Analysis of Impedance Characteristics of TMMD-HIS & Its effect of Low Profile Antennas

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Abstract - A navel tunable multi layer multi dielectric high impedance surface reflector proposed in present paper is a three dimensional high impedance surface which exhibiting abnormal impedance characteristics. This property of high impedance not allow the low profile antennas to shorting out with under lying TMMD-HIS during stop band region. Proposed structure is operating at 1.9GHz. Present paper A TMMD-HIS unit cell impedance characteristics are analyzed theoretically and compared with numerical values obtained in simulation software.

Keywords— *TMMD-HIS, Impedance, PMC.*

I. INTRODUCTION

Modern wireless communication systems are demanding the low profile antennas. Because of its characteristics such as light weight, easy of manufacturing etc,. But these antennas are suffering with some drawbacks. In order to overcome from some of drawbacks the electromagnetic band gap structures are introduced in these structures. Present paper is concentrating on the effects that are encountered by the introduction of TMMD-HIS as ground reflector for low profile antenna is investigated.

II. STRUCTURAL MODEL

The architecture shown in figure 1 is consists of two dielectric materials which are arranged in ascending order. The metal protrusions of square shaped are printed over its top faces. A metal conducting via are used to connect these protrusions with ground reflecting surface. A unit cell of proposed model is presented because the complete structure is developed by the combination of these unit cells in by directional fashion.

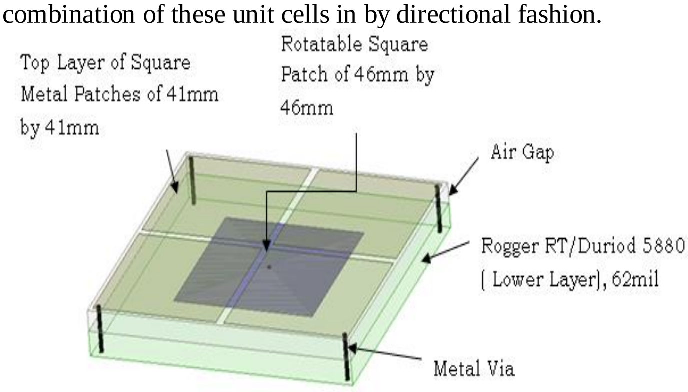

Fig 1: Structural model

III. DESIGN SPECIFICATION

The unit cell has following dimensions thickness t =62mil, diameter of via d =0.65mm, width of patch w = 41mm, gap g = 2.5mm, hidden layer patch width Hw = 46mm height of MMD-HIS h = 3mm and relative permittivity of ε_r =2.2 with loss tangent 0.0009, an air is considered as another dielectric to obtain an operating frequency of 1.89GHz.

IV. ANALYSIS OF TMMD-HIS

The surface impedance can be defined as the ratio of tangential electric fields to tangential magnetic fields can be represented as

$$Z_s = \frac{E}{H} \qquad \text{----------------------} \quad (1)$$

For good conductors, the surface impedance is very low because the ratio of electric field to magnetic field is very small. For high impedance surfaces, the ratio in Equation 5.2.1 is very high, because the tangential magnetic field at the surface is zero. Same surface some time called as "magnetic conductor".

For better understanding of concept. The reflection phase is related to the surface impedance in the following way. Consider a forward-running wave impinging on the surface, with electric and magnetic fields are given by an expressions below.

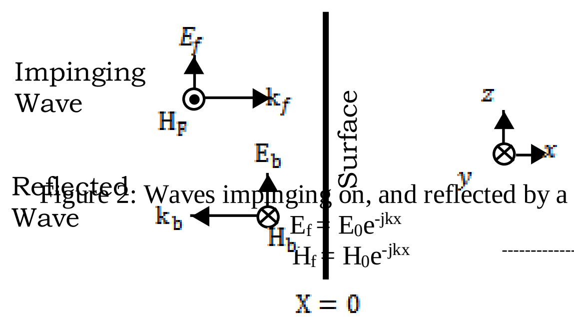

Figure 2: Waves impinging on, and reflected by a surface

$$E_f = E_0 e^{-jkx}$$
$$H_f = H_0 e^{-jkx} \qquad \text{-------------} \quad (2)$$

The wave is reflected from the surface, and the backward-running wave has a similar form, as indicated in figure 2.

$$E_b = E_0 e^{jkx}$$
$$H_b = -H_0 e^{jkx} \qquad \text{--------} \quad (2)$$

The negative sign on the magnetic field is due to the convention of the right hand rule. The field components of forward and backward running waves are related with free space impedance as.

$$\left|\frac{E_f}{H_f}\right|=\left|\frac{E_b}{H_b}\right|=\eta \qquad \text{------------} \quad (3)$$

The fields of the standing waves, and impedance, can be expressed in terms of the phase shift that occurs upon reflection from the surface.

$$\frac{E_{(x)}}{H_{(x)}}=\frac{E_f(x)+E_b(x)}{H_f(x)+H_b(x)}=\eta\ \frac{e^{-jkx}+e^{-jkx+j\phi}}{e^{-jkx}-e^{jkx+j\phi}}=j\eta\cot\left(kx+\frac{\phi}{2}\right) \qquad \text{---------------} \quad (4)$$

From the above equation, we can conclude one point that the apparent reflection point moves forward in the positive X-direction, the reflection phase, Ø, starts decreasing. This point is illustrated here.

The frequencies which are far below resonance, the surface has low impedance, so the node of electric field and antinode of the magnetic field are in contact with surface, as shown in figure 3. This resembles the reflection from ordinary metal surface. The figure shows the electric and magnetic fields of a standing wave, which are the vector sums of the two running wave fields. The solid vertical line indicating the position of the surface. It is assumed that the sign shown for each field is consistent with the field direction of an incoming wave. This convention ensures that the TMMD-HIS surface has positive, real impedance, while a radiating surface has negative, real impedance.

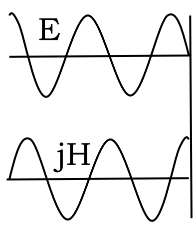

Figure 3: Standing wave fields at a frequency far below resonance

When the frequency increases (The frequency considered here is just below the resonance frequency and near to the TM band edge), the phase slopes downward, in reflection characteristics. At this stage the surface just has higher impedance, so the electric field no longer has a node at the surface. As if the effective reflection point of the surface were receding, the standing wave shifts forward, toward the surface, as indicated by the arrows in figure 4.

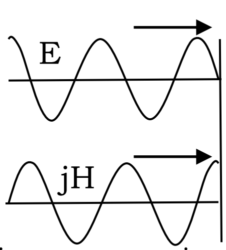

Figure 4: Standing wave pattern just below resonance

At this stage, the surface impedance is positive imaginary, or inductive, but its value is much higher than that of a conventional metal surface.

At the resonance frequency, the surface impedance is very large, so the node of electric field and antinode of magnetic field are at the surface. Shown in figure 5. The surface at this stage functions like artificially high impedance surface.

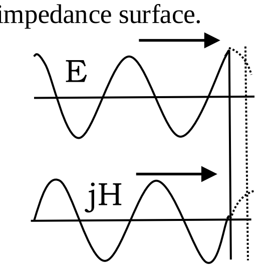

Figure 5: Standing wave pattern at resonance frequency

When frequency increases further (frequency considered here is just above the resonance frequency and near to the TE band edge), the phase slopes farther downward towards -180 degree. The standing wave continues to shift toward the surface. The impedance has switched sign, and the surface is now capacitive. This is indicated in figure 6, in which the magnetic field is now negative.

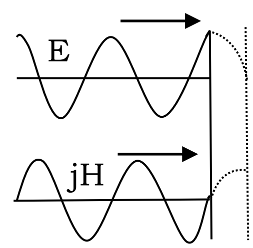

Figure 6: Standing wave pattern just above resonance

At frequencies that are much higher than resonance, the surface impedance has returned to near zero. The reflection phase has returned to the same point where it started, but it has gone through one complete cycle. Shown in Figure 7. As the frequency is increased through the resonance, it is as if the effective reflection plane has slipped into the surface by one-half wavelength.

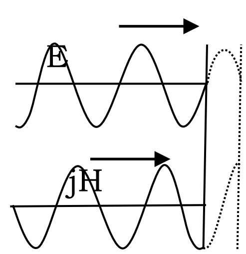

Figure 7: Standing wave pattern for a frequency far above resonance

V. IMPEDANCE CHARACTERISTICS

The proposal is implemented in software tool of Ansoft HFSS. This is using Finite Element method of numerical technique for analysis. To obtain the reflection phase characteristics the unit cell is placed in an air box. The sides of air box are applied with periodic boundaries. Form the top plane is made to incident normally.

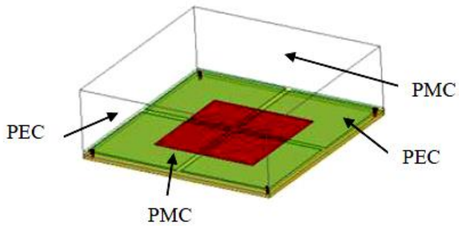

Figure 8: Periodic boundaries

This engineered artificial magnetic material of TMMD-HIS exhibits abnormal characteristics i.e. imaginary impedance dominates the real impedance of structure at particular instant. The magnitude, where the imaginary impedance value is high, is considered as operating point of this structure. This value always lies within the stop band region. In our structure, the artificial high impedance magnitude is high at 1.9GHz that is well within the limit of stop band range. The starting point of band gap is at 1.87GHz and ends at 2.1GHz

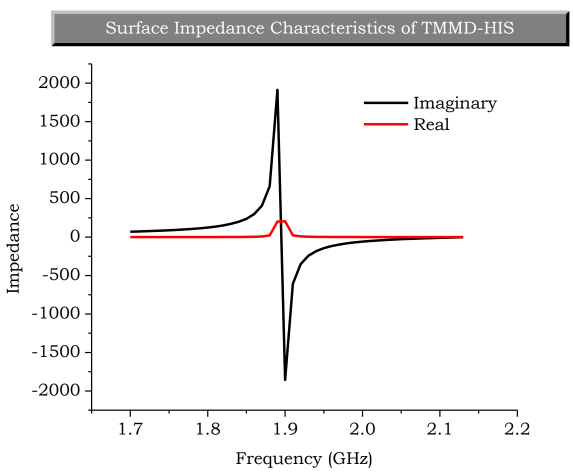

Figure 9: Impedance Characteristics

When an antenna is constructed over the TMMD-HIS reflecting surface, will experience a free space impedance on one side and TMMD-HIS impedance on other side. When mounted antenna is operating with a frequency which is far away from resonance frequency of high impedance surface, where TMMD-HIS surface exhibits low impedance functions like conventional metal reflector. Then the current propagation in an antenna is equal and opposite to the current in surface hence an antenna get shorted out with nearby conductors, which effects the radiation characteristics of antenna so radiation efficiency will be poor. When mounted antenna is operating nearer to resonance frequency of TMMD-HIS, Since the TMMD-HIS exhibiting higher impedance when compared with free space impedance, then the current propagation in an antenna is equal in phase with the current in surface hence which doesn't allow antenna to shorted out. During this range antenna possesses improvement in radiation efficiency.

VI. CONCLUSION

The impedance characteristics of TMMD-High Impedance region is initially studied theoretically. Latter it was implemented in Ansoft HFSS software. The structures model of TMMD-HIS is analyzed using a numerical technique of Finite Element Method. Where graphically visualized the abnormal characteristics of TMMD-HIS. Its effect on mounted antenna is explained.

VII. REFERENCES

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