Understanding of the Coupling Reduction Effects in Microstrip Arrays Antennas Using High Impedance Surface (HIS)

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Abstract In this paper, bandgap high impedance surfaces (HIS) are designed to form electromagnetic barriers. The mutual coupling effects between two array antennas are characterized with and without the insertion of the HIS.

Keys words: planar antenna array, coupling reduction, high impedance surfaces, electromagnetic bandgap structures.

I. INTRODUCTION

The major characteristic of EBG or HIS structures is to exhibit band gap feature in the suppression of surface-wave propagation [1]. Since the mutual coupling between the antenna elements and arrays is principally carried by the wave surface, the use of HIS can help to attenuate their level if the topology and implementation are carefully designed (Fan Yang's studies and Li Yang [2, 3]).

This paper focuses on the design and optimization of a Mushroom Fork-like high impedance surface. It is inserted between the antenna circuits (distance d). Their full wave simulation S parameters are determined and compared to the measured ones. The Mushroom Fork-like HIS have complex geometry which allows more adjustment of their geometrical dimensions to achieve good performances (large band and deep attenuation).

In order to validate our study a Four-Element patch array antenna, chosen as unit radiative element, is designed and optimized. The mutual coupling coefficient is strongly dependant on spacing distances d and the size of the HIS barrier.

For a distance $d=2\lambda$, the coupled antennas are fully characterized. Their E- and H- planes radiation patterns return loss and mutual coupling factors are measured and compared to the full wave CST simulations.

II. ANTENNA ELEMENT

The array antenna element, as shown in Figure 1, is composed by four patches with a distance D in both directions [7]. The network includes a center line of $100\ \Omega$ fed at its center by an ideal $50\ \Omega$ source. In each one of the splitting

points there are two $100\ \Omega$ lines going to the patches. The array antenna has a resonant frequency of 10 GHz.

Figure 1. (a) Array antenna design with four patch elements, $W=8.4\text{ mm}$, $L=7.5\text{ mm}$, $w1=w2=w3=1.28\text{ mm}$, $L3=1.85\text{ mm}$, $D=0.5\lambda_{10\text{GHz}}$. (b) The simulated antenna Return loss.

III. HIS DESIGN

Fig. 2 shows the HIS chosen to form the electromagnetic barriers for the decoupling effect. It is a Mushroom Fork-like metallic periodic structure etched on a dielectric substrate.

As shown by Fig. 2, each element of this HIS structure consists of a square metal patch with a slot etched on it and a stretched strip. The patch is connected to the ground plane by a metal plated via. The dimensions of the unit cell are given in the figure caption.

The operation mechanism of the EBG structure can be explained by an LC filter array: the inductor L results from the current flowing through the vias and the capacitor C due to the gap effect between the adjacent patches.

$$BW = \frac{\Delta\omega}{\omega} = \frac{1}{\eta} \sqrt{\frac{L}{C}}$$

$$\varpi = \frac{1}{\sqrt{LC}}$$

where $\eta = 120 \pi$ is the free space impedance.

Fig. 3 gives the simulated magnitude and phase angle of the HIS return loss. A band gap of 20% is achieved.

Figure 2. Fork-like HIS.

Figure 3. The simulated HIS Return loss phase angle (Deg.).

IV. COUPLED ANTENNA AND RESULTS

Fig. 4 shows the analyzed structure. The HIS electromagnetic barrier is inserted between the coupled antenna to suppress the surface waves.

Figure 4. The studied coupled antennas structure

Some full wave's simulated and experimental results are obtained for the S parameters and radiation patterns in both E- and H- planes. Figure 5 shows the simulated return loss (S11) and coupling coefficient (S21). For comparison, the results are presented without and with the HIS structure.

The simulated results (Fig. 5) show a resonance frequency $f_0=10$ GHz with a very low coupling level, below -40 dB over all the X band frequency and better than -60 dB by using the HIS. The adaptation of the antenna is reinforced by the HIS.

The measured results (Fig. 6) are in total concordance with the simulations. The resonance frequency is $f_0=10$ GHz with a very good adaptation (< -20 dB). The coupling level is very good, below -48 dB over all the X band frequency.

Figure 7 shows the surface current distribution around the arrays at the frequency $f_0=10$ GHz without the HIS (Fig. 7(a)) and with the HIS structure (Fig. 7(b)). It is observed that with the HIS structure, the surface current is suppressed by the fork-like HIS structure. In the other case; without the HIS, the surface wave is propagated straightly from array 1 to array 2.

Figure 5. Simulated result of the S parameters of conventional and with fork-like HIS.

Figure 6. Experimental result of the S parameters of conventional and with fork-like HIS.

Figure 7. Surface current of .

V. CONCLUSION

In this work, a Mushroom Fork-like HIS is designed to operate as an electromagnetic barrier to suppress the surface waves. Prototypes coupled antennas fabricated with various spacing distance and HIS shape and sizes are characterized experimentally and by using full wave's simulations. We present here only the results obtained for $d=2\lambda_{10\text{GHz}}$ at 10 GHz.

More results and parametrical studies will be presented in detail during the presentation.

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