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Mutual Coupling Reduction In Antenna Arrays Using Jerusalem Cross Periodic Structure

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Abstract

When the number of antenna elements is placed in forming the arrays, mutual coupling between the antenna elements is a critical issue. A periodic structure is used to suppress mutual coupling between elements in a micro strip array In this paper, Jerusalem cross periodic structure is proposed as an effective solution for reducing mutual coupling in a micro strip array antenna that consists of two elements. Applying the proposed periodic structure in the substrate and between the patches is simulated and studied. Simulation results show the improvement of mutual coupling by adding Jerusalem cross periodic structure to the antennasubstrate.

Keywords: Microstrip array antenna, Mutual coupling, Jerusalem Cross periodic Structure

Introduction

In the design of microstrip arrays, mutual coupling between elements is an important factor to be considered. Many studies have indicated that the mutual coupling between elements can degrade seriously the performances of the array, leading to impedance mismatch, side-lobe level increases, scanning blindness occurrence and reduced gain [1]. Mutual coupling between microstrip elements is caused by both space waves and surface waves. A surface wave has a significant impact on the mutual coupling when the thickness of the microstrip substrate is greater than 0.3λ0/ (2p/p1r) [2], where λ0 is the operating wavelength in free space and ε_r is the relative permittivity of the substrate. In the past decades, many methods have been developed to reduce the mutual coupling caused by surface waves between antenna elements in the design of microstrip arrays. In [3–4], shorted patches were proposed to prevent excitation of the surface wave mode. In [5–6], electromagnetic bandgap (EBG) structures were used to suppress mutual coupling. An EBG structure creates a so called electromagnetic crystal to suppress surface-wave propagation, and thus, unwanted mutual coupling between elements is decreased. Recently, defected ground structures (DGS), which are formed by etching patterns on the ground plane, have received much attention. As a resonator, the DGS is a compact structure. This advantage has resulted in its various applications, such as microwave filters and matching circuits as well as suppressing harmonic and cross polarisation in microstrip antennas [7–8]. However, there are only a limited number of results published concerning the suppression of mutual coupling between elements in antenna arrays [9-10].

In this work, a Jerusalem cross periodic structure is proposed to decrease the mutual coupling of the microstrip antenna arrays. The proposed periodic structure was applied in the substrate and between the patches. The presented simulation results are obtained with the finite element based Ansoft High Frequency Structure Simulator (HFSS). The parametric study is presented on the length, width and Jerusalem cross spacing in the direction of X and Y. The performance comparison of the proposed antenna and reference dielectric show that Jerusalem cross has a good application potential to improve the mutual coupling

Jerusalem Cross Periodic Structure

Frequency selective surfaces (FSSs) are periodic structures designed on a substrate with metal (usually copper). These metallic structures behave like inductance and capacitance towards incident waves and hence behave as spatial filters. Therefore, an FSS either blocks or passes waves of certain frequencies in free space. Different shapes like a circle, square, cross, hexagon, tripole etc. can be used for FSS fabrication (on the metallic side of a dielectric substrate). Any of these specific shapes are placed periodically a half wavelength from one another (mostly in two dimensions). The wavelength is calculated from the frequency of operation (free space). An FSS can be designed to function as a high-pass, low-pass, band stop or band pass filter

Fig 1 illustrates some of the most common of the various element shapes: circular, rectangular/dipole, three or four legged dipole, cross dipole, ring, square loop, and gridded square loop [11, 12].

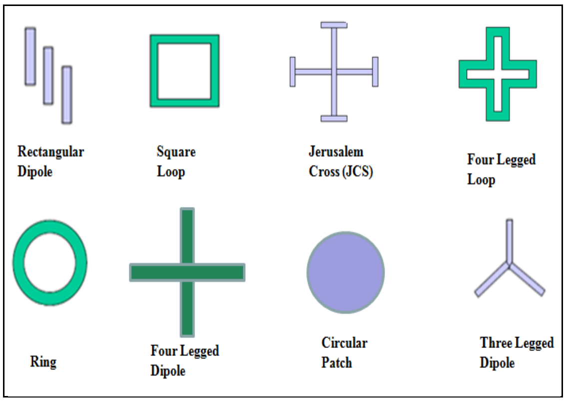

Figure 1: FSS element shapes

In this paper, Jerusalem cross periodic structure is used , which is depicted a unit cell in Fig. 2. Fig. 3 shows the array antenna loading by 3 rows of Jerusalem cross periodic structure.

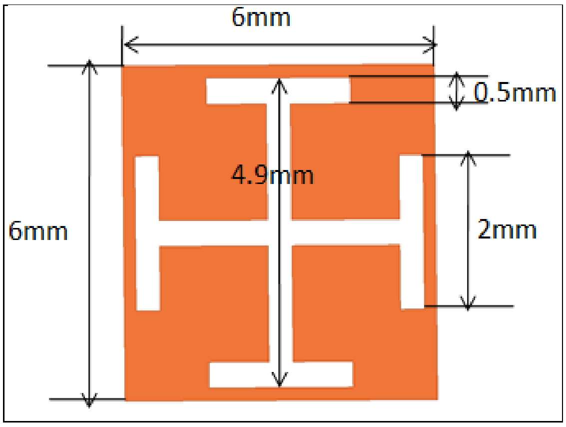

Figure 2: A unit cell of Jerusalem Crossperiodic structure

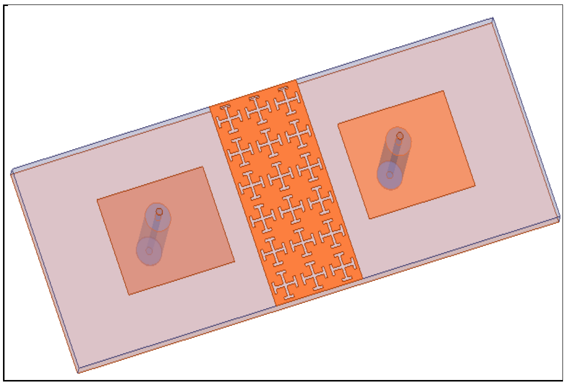

Figure 3:. Array antenna with of Jerusalem Crossperiodic structure for 3 rows

Geometry of The Array Antenna

The microstrip array antenna consists of a FR4 substrate and two patch elements; the distance of the elements is considered 28mm. The substrate's dimension and relative permittivity, ε_r, are 100mm×36mm. Fig. 4 illustrates the array antenna structure used in the simulation. In this research, the length and width of the patches are L=22mm and W=17.2mm and the antenna resonant at the frequency 5GHz

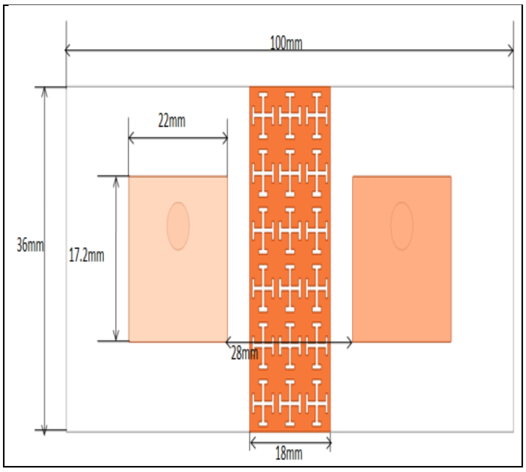

Figure 4: Top view of two coupled microstrip antenna patches

Results and Discussion

The effect mutual coupling with and without FSS as shown in Fig.64.7 In this case, the 2x1 array is used and simulated with and without FSS. It can be observed that the antenna resonate around 5GHz and the mutual coupling level changes so that the surface waves are suppressed. The mutual coupling is decreased by increasing the length so that, the amount of mutual coupling is decreased to around -29.0677dB to -20.1315dB and gain is increased 10.7694dB to 11.0761

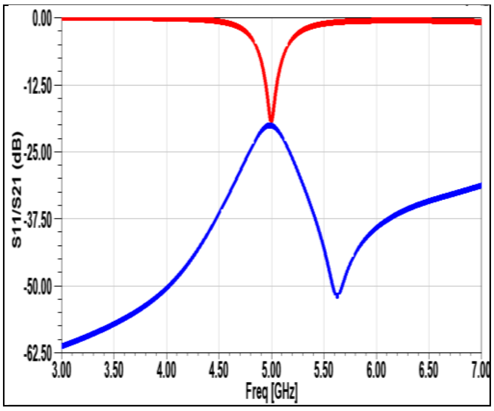

Figure 4.1: S_{11} Vs S12 and frequency without FSS

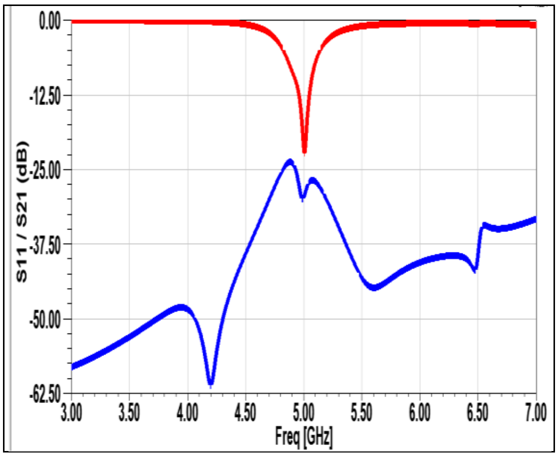

Figure 4.2: S_{11} Vs S21and frequency with FSS

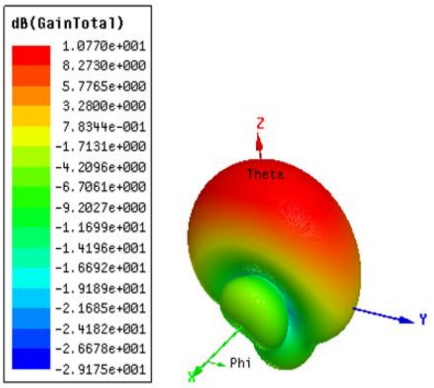

Figure 4.3: Gain Vs theta and frequency without FSS

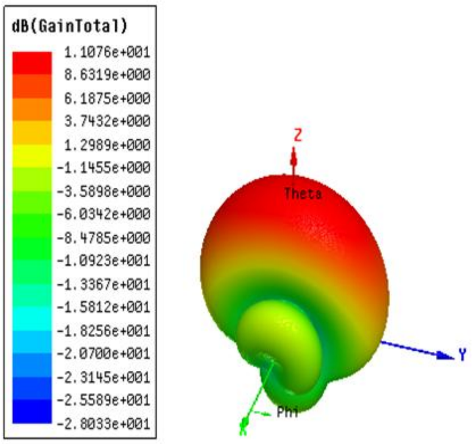

Figure 4.5: Gain Vs theta and frequency with FSS

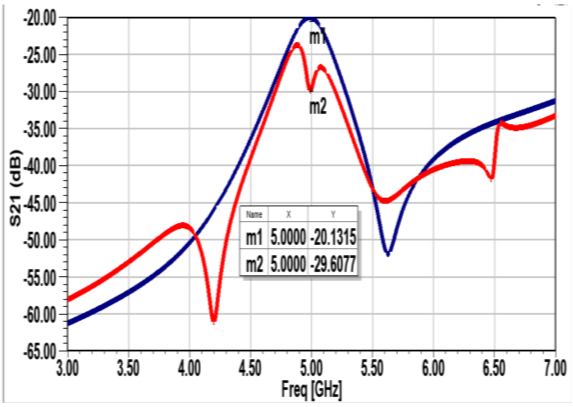

Figure 4.6: Comparison of S21 Vs Frequency with and without Frequency

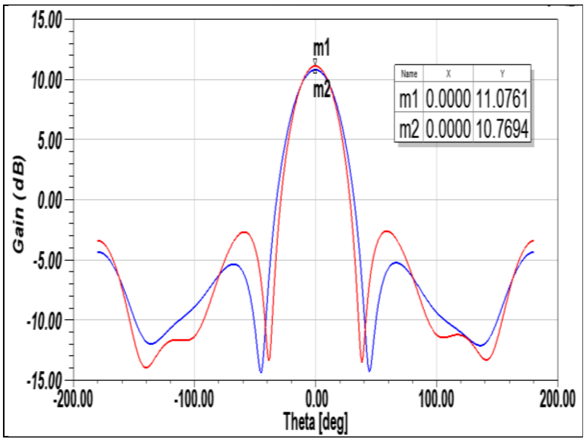

Figure 4.7: Comparison of Gain Vs theta with and without frequency

Conclusion

In this paper, Jerusalem cross periodic structure was used for reducing the mutual coupling between the elements of the microstrip array antenna. The parameters of the structure (length, width, spacing and the number of the rows) were studied. The proposed antenna with Jerusalem cross periodic structure had the 9.4762dB reduction of mutual coupling in comparison with the microstrip array antenna used alone. This comparison demonstrated that the unique capability of the Jerusalem cross periodic structure reduced mutual coupling by suppressing surface waves

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