Mutual Coupling Reduction Between Patch Antenna Array Elements Using Metamaterial Z shaped Resonators

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Abstract **— Modern wireless communication systems require compact design, low cost and simple structure antennas to insure reliability, agility, and high efficiency characteristics. This paper presents a microstrip antenna array designed for 8 GHz applications. To reduce the mutual coupling effects, a Z shape metamaterial structure was imprinted in the microstrip antenna array composed of two elements. Simulation results show the improvement of mutual coupling by adding Z shape metamaterial structure to the antenna substrate. The proposed structure reduces mutual coupling by 19 dB. The simulation has been performed by using HFSS simulator.**

Keywords- Antenna, metamaterial, FSS, mutual Coupling.

1 INTRODUCTION

Microstrip antenna array on high dielectric constant substrate is designed, for high gain applications, beamforming or diversity purposes [1–4], where compactness is considered as an important issue. However, the use of high dielectric constant substrate can induce some weaknesses. One of the problems is the excitation of surface waves, which can incur mutual coupling between the adjacent elements.

The mutual coupling is one of the major sources of degradation in array performance such us poor radiation, efficiency and low gain, [5]. Therefore, achieving a high degree of isolation between elements is an important approach for improving the array performance.

To overcome the problem of mutual coupling, various methods have been studied in the literature such as loading electromagnetic band-gap (EBG) structures [6], defecting ground structures (DGSs) between elements [7], using concave rectangular patches [8], and grooving the dielectric [9].

Metamaterials structures were also used for coupling reduction such us the split ring resonators (SRR). These materials exhibit either negative permeability and/or negative permittivity [10] and can suppress electromagnetic wave propagation in certain frequency band [11].

In this paper, a Z shape structure is proposed to reduce the mutual coupling of the microstrip antenna arrays. The proposed periodic structure was applied between the antenna elements. The effects of the inclusion of this structure on antenna performances are also studied. The comparison between the proposed antenna and a reference antenna show that metamaterial has a good application potential to improve the mutual coupling.

2 GEOMETRY OF THE ARRAY ANTENNA

A rectangular patch antenna array with two elements, as shown in Figure 1, is etched on a common ground plane with each element resonating at 8.3 GHz.

The antenna array dimensions, material properties and operating frequency details are shown in Table 1.

Parameters	Specifications
Frequency of Operation	8 GHz to 8.6 GHz
Resonant Frequency	8.3 GHz
Substrate	FR4 eposy
Height of the Substrate	1.58 mm
Length of the Patches (L)	10.6 mm
Width of the Patches (W)	7.6 mm
Dielectric constant	4.4
Distance between antennas (d)	7.8 mm

Table 1: Parameters of the microstrip antenna array.

A separation of 8.3 mm was maintained between the antennas. This yields to a central resonant frequency, around 8.3 GHz, as shown in Figure 2.

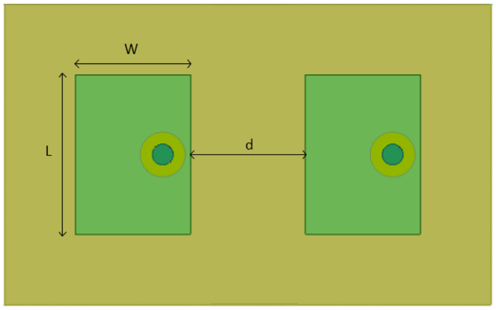


Figure 1: Top view of two coupled microstrip antenna patches without isolation.

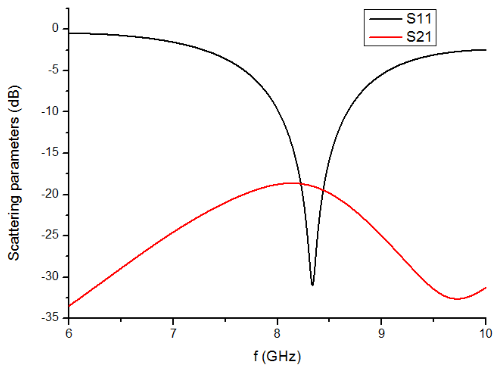


Figure 2: Simulated Return loss and mutual coupling for the microstrip antenna array.

3 Z SHAPED FOR MUTUAL COUPLING IMPROVEMENT

In this paper, we use a periodic Z shape structure, which is depicted by a unit cell in Figure 3. The proposed Frequency Selective Surface (FSS) is composed of two Z shape resonators printed on opposite sides and along the diagonal direction of a dielectric substrate. The parametric values of Z shaped

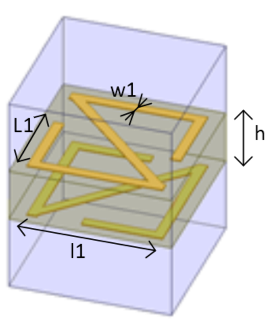


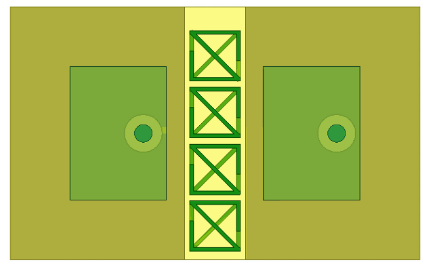
Figure 3: Z shaped MTM structure.

metamaterial (MTM) structure are shown in Table 2.

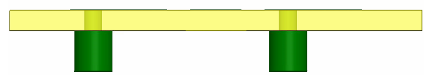
As depicted in Figure 4, a 1x4 Z shape matrix is inserted between two rectangular elements of an

Parameters	Dimension (mm)
Height of Substrate (h)	1.58 mm
Length of Z (l1)	4 mm
Width of Z (w1)	0.3 mm
Thickness of Metal Strip (t)	35 μm
Width of the arms in the front (L)	2.4 mm

Table 2: Parameters of the Z shape pattern.



(a) Top view



(b) Side view

Figure 4: Two coupled microstrip antenna patches with isolation.

array. Each element has a size of 4x4 mm and their edge to edge separation is 0.5 mm. The Z shape dimension and spacing are optimized to get lowest mutual coupling.

4 RESULT AND DISCUSSION

The mutual coupling between the antennas was analyzed in terms of electrical isolation ($S21$) between the two ports of the microstrip antenna array.

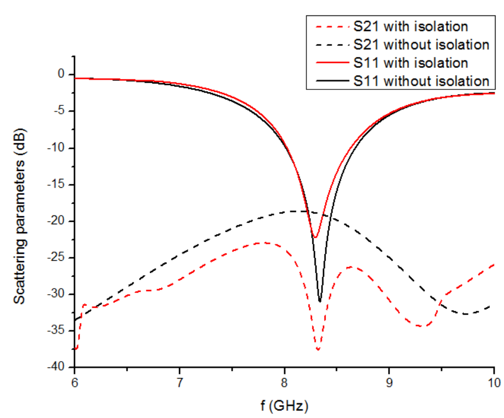


Figure 5: Scattering parameters of microstrip antenna array with and without Z Shape metamaterial.

Figure 5 shows the return loss variation in terms of frequency for the antenna system array with and without Z shape structure. It can be noticed that the two antennas resonate at around 8.3 GHz and the return losses are −30 dB for the reference array antenna and −22 dB for the modified one.

Figure 5 shows also that if the Z shape structures are employed, the mutual coupling level changes, and there is around 19 dB mutual coupling reduction to obtain the same amount of mutual coupling as obtained without Z shape structure. The resonant frequency of 8.3 GHz falls inside the metamaterial stop band so that the surface waves are suppressed.

5 CONCLUSION

In this paper, an antenna array system has been designed with improved miniaturization performance by reducing the mutual coupling between the elements. The proposed antenna with periodic Z shape structure has a 19 dB reduction of mutual coupling compared to the microstrip array antenna without considered FSS. This comparison has proved the ability of the metamaterial structure to reduce mutual coupling by suppressing surface waves.

References

[1] Lee, J.-H. and C.-C. Cheng, "Spatial correlation of multiple antenna arrays in wireless communication systems", Progress In Electromagnetics Research, Vol. 132, 347-368, 2012.

[2] Quan, X. L., R.-L. Li, J. Y. Wang, and Y. H. Cui, "Development of a broadband horizontally polarized omnidirectional planar antenna and its array for base stations", Progress In Electromagnetics Research, Vol. 128, 441-456, 2012.

[3] Wei, K., Z. Zhang, and Z. Feng, "Design of a dualband omnidirectional planar microstrip antenna array", Progress In Electromagnetics Research, Vol. 126, 101-120, 2012.

[4] Costa, F., S. Genovesi, and A. Monorchio, "A frequency selective absorbing ground plane for low-RCS microstrip antenna arrays", Progress In Electromagnetics Research, Vol. 126, 317-332, 2012.

[5] Islam, M. T., R. Azim, and A. T. Mobashsher, "Triple band-notched planar UWB antenna using parasitic strips", Progress In Electromagnetics Research, Vol. 129, 161-179, 2012.

[6] A. Azarbar and J. Ghalibafan, "A Compact Low-Permittivity Dual-Layer EBG Structure for Mutual Coupling Reduction", International Journal of Antennas and Propagation, Vol. 2011, Article ID 237454, 2011.

[7] D. Hou, S. Xiao, B.-Z. Wang, Li Jiang, J. Wang and H. Wei, "Elimination of scan blindness with compact defected ground structures in microstrip phased array", IET Microwave Antennas Propagation, Vol. 3, No. 2, pp. 269-275, 2009.

[8] Sh. Mohanna, A. Farahbakhsh, S. Tavakoli, and N. Ghassemi, "Reduction of Mutual Coupling and Return Loss in Microstrip Array Antennas Using Concave Rectangular Patches", International Journal of Microwave Science and Technology, Vol. 2010, Article ID 297519, 2010.

[9] J. G. Yook, and L. Katehi, "Micromachined microstrip patch antenna with controlled mutual coupling and surface waves", IEEE Trans. Antennas Propagat., Vol. 49, pp.1282-1289, 2001.

[10] L. Bin, W. Bain, and L. Changhong, "Study on high gain circular waveguide array antenna Using metamaterial structure", Progress In Electromagnetics Research, Vol. 60, pp. 207219, 2006.

[11] T. J. Cui, R. Liu, B. Zhao, X. Q. Lin and H. F. Ma, "A New Metamaterial Structure to Amplify Evanescent Waves and Its Applications in Microwave Components", International Workshop on Antenna Technology, pp. 527-527, 2007.