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Frequency-Selective Surface for Reduced Mutual Coupling among Closely Spaced Array Antenna

In this paper, we proposed a frequency selective surface (FSS) as a mechanism to reduce the mutual coupling between the closely spaced circular patch microstrip antennas operating at 5.2 GHz. The results show that S_{12} has been reduced to about -36 dB, in comparing without using FSS array were -16 dB.

Keywords: Frequency selective surface; Circular patch antenna; Array antenna; Mutual coupling
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1. Introduction

Mutual coupling describes energy absorbed by one antenna receiver when another nearby antenna is operating. That is, mutual coupling is typically undesirable because energy that should be radiated away is absorbed by the nearby antenna. Hence, mutual coupling reduces the antenna efficiency and performance of antennas in both the transmitting and receiving mode [1]. Mutual coupling in antenna arrays is a topic of continuous research interest to researchers and engineers. Since the application of antenna arrays has been extended to many areas in modern days, the study of the mutual coupling phenomenon has become a popular and important topic of research, many ways and techniques were demonstrated to reduce among array antennas [2]. The defected ground plane DGP [3-5], electronic band gap EBG [6-7], frequency selective surface [8-9], and metamaterial [10-12] are the most popular methods for decoupling the antennas.

In this paper, a we present new approach which integrates FSS and EBG as tool to reduce the mutual coupling between two adjacent circular patch microstrip antenna operating at 5.2 GHz.

2. Antenna Design and Simulation

According the theory of designing the circular patch antenna at a dominant mode TE_{mn} or TM_{mn} modes, the resonant frequencies for the TM_{mn} modes can be written as [13]

$$f_{r_{mn}} = \frac{1}{2\pi\sqrt{\varepsilon_e}}\left(\frac{\chi'_{mn}}{a}\right) \quad (1)$$

Since the dimension of the patch is treated a circular patch, the actual radius of the patch is given by

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}}$$

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

Since fringing makes the patch electrically larger, the effective radius of the patch is used and is given by

$$a_e = a\left\{1 + \frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \quad (3)$$

Hence, the resonant frequency for the dominant TM_{11} is given by

$$f_{r_{11}} = \frac{1.841c}{2\pi a_e\sqrt{\varepsilon_e}} \quad (4)$$

where c is the free space speed of light.

According to the above equation, the proposed circular patch antenna has the following dimensions, the radius of the patch is 11.15 mm supported by a dielectric substrate of thickness 1.6 mm made from Duriod of dielectric constant of 2.2 and tangent loss 0.0009, the dimension of the substrate is 30×30 mm as shown in Fig. (1).

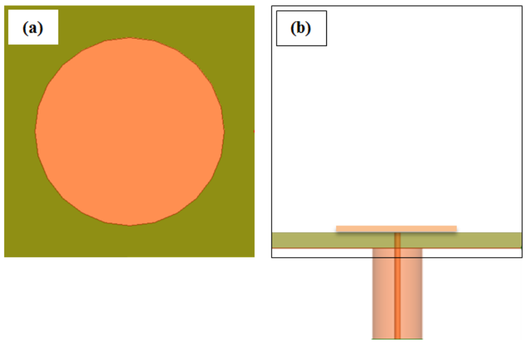

Fig. (1) proposed antenna (a) xy-plane and (b) yz-plane

The simulation is done with Ansoft™ HFSS-13 to study the parameters of the proposed antenna such as S_{11}, VSWR and radiation pattern in Fig. (2).

As shown from Fig. (2) the return loss null about -30 dB refers to the good impedance matching between the probe and the characteristic impedance of the patch by selecting the appropriate feed location, the radiation pattern is monopole radiation

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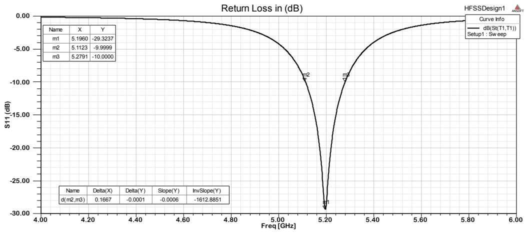
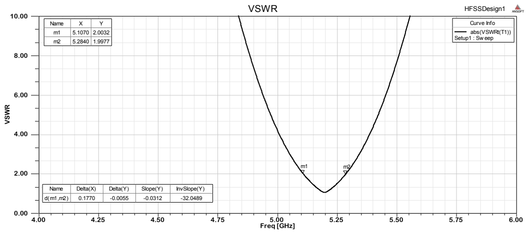
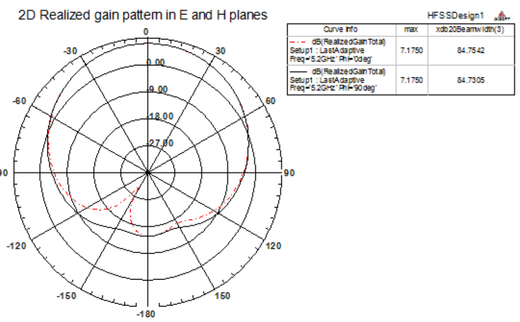
like and the gain is about 7 dB with overall efficiency 3%.



(a)



(b)



(c)

Fig. (2) Primary results (a) S_{11}, (b) VSWR, and (c) Realized gain

3. Array Antenna

In order to enhance the antenna's radiation performance the antenna, the array antenna consisting of two elements is shown in Fig. (3).

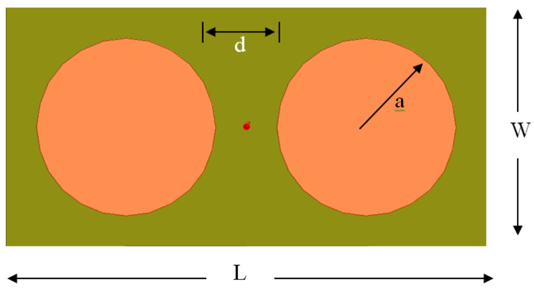


Fig. (3) Array antenna of two elements

The simulation is done also with HFSS. The results of simulation are depicted in figures (4) and (5).

From the simulation results we can conclude that the coupling factor S_{12} is about -17 dB, while the radiation pattern is enhanced with a gain of 9 dB and high directive gain.

4. Decoupling technique

In order to reduce the coupling parameter S_{12} between the array elements (undesirable energy loss) a periodic structure of rectangular slots as shown in Fig. (6), the optimum values of the cell are listed in table 1.

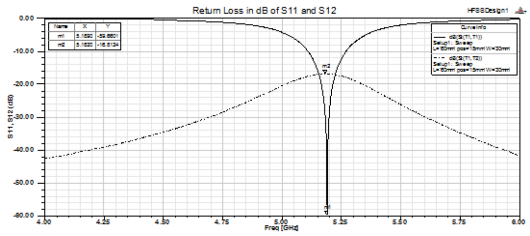
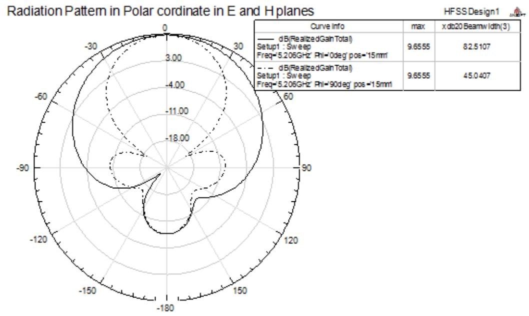
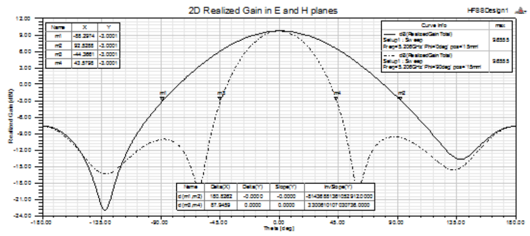


Fig. (4) Return loss S_{11} and coupling factor S_{12} of array antenna



(a)



(b)

Fig. (5) Radiation pattern (realized gain) of array antenna (a) polar coordinate and (b) rectangular coordinate

Table (1) Dimensions of decoupling cell (all dimensions in mm)

L_1	L_2	w_1	w_2	L_c	W_c
12.3	14.5	1.5	1.2	30	7.4

After numerous parametric studies for selecting the optimum values to make an FSS at 5.2 GHz. The antenna array model with FSS is illustrated in Fig. (7).

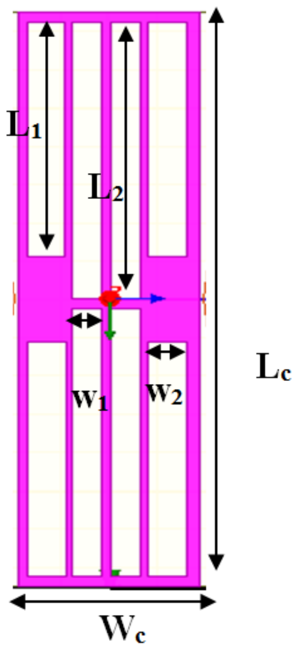


Fig. (6) Dimensions of the decoupling cell

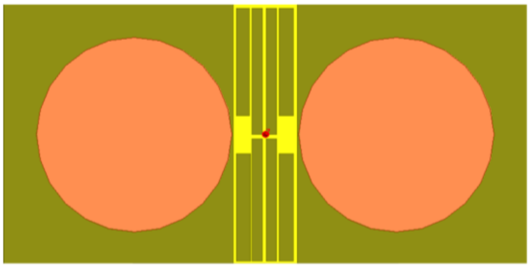


Fig. (7) Array antenna with decoupling cell

The simulated results are illustrated in the figures (8) and (9).

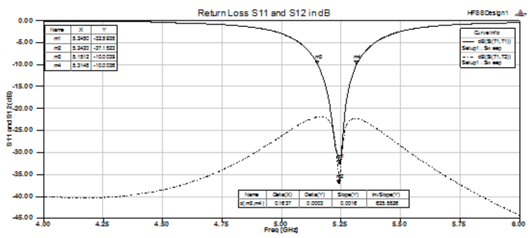
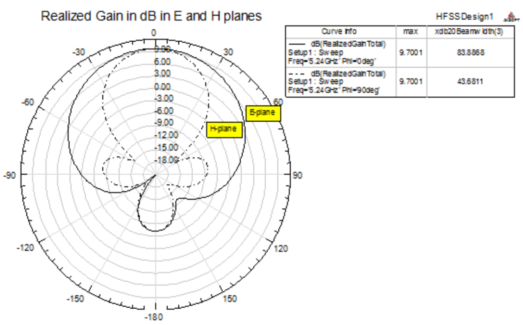
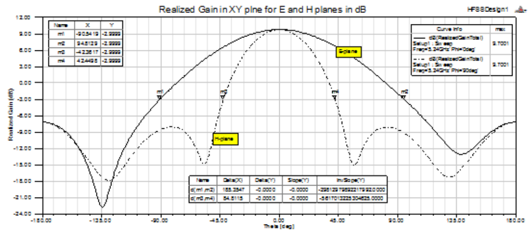


Fig. (8) Return loss S_{11} and decoupling S_{12} scattering matrix



(a)



(b)

Fig. (9) Realized gain in (a) polar and (b) rectangular coordinates in E and H-planes

As shown from Fig. (8), the decoupling value is about -37 dB compared with -17 dB without decoupling cell, the isolation is to be excellent, as shown in Fig. (10).

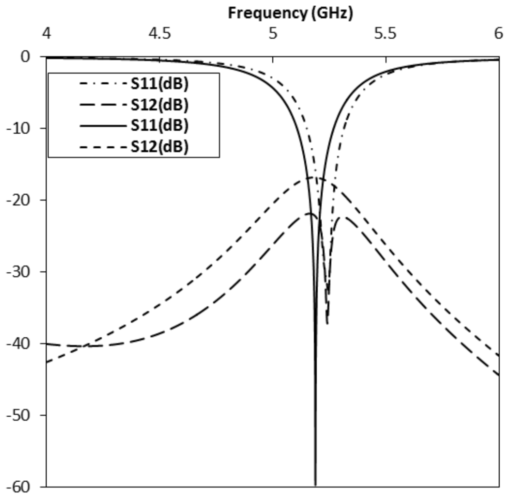


Fig. (10) Comparison between graphs of S_{11} and S_{12} with (red solid and dashed curves) and without (black solid and dashed curves) decoupling cell

5. Conclusion

From the above comprehensive results one can conclude that using of the proposed decoupling cell FSS is a good tool to improving the isolation parameter of the scattering matrix (S_{ij}). This proposed array antenna can efficiently be used in wireless communication such as Wi-Fi.

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