International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 8, October - 2012

Designing Superdirective Patch Antenna Array Using Metamaterial

Pranshu Sharma[1], Dinesh Arora[2], Hitender Gupta[3]
Student fellowship[1], Assistant professor[2], Assistant professor[3],

Abstract

Microstrip patch antenna has certain drawbacks of low gain, narrow band, and surface wave losses. In this paper the solution method used is a patch array with SRR metamaterial, which reduces the mutual coupling between the patch elements, thereby improving the directive gain and reducing the surface waves. A rectangular microstrip patch antenna that meets the requirement of operation at (8.29 GHz), the proposed configurations are simulated and analyzed in Ansoft High Frequency Structure Simulator. The VSWR, radiation patterns for gain and S11 performance are used for the analysis of the final design. Feed point on the patch that gives a good match of 50 ohm, input impedance was found by a method of trial and error.

1. Introduction

A microstrip patch antenna has the advantages of low cost, light weight, and low profile planar configuration. However, they suffer from the disadvantage of low directive gain [1-2]. Gain improves as the number of patch elements increase, and simultaneously as the mutual coupling between the elements reduces. This paper presents the use of three patch elements in an array with an SRR which acts as a filter for the resonating frequency. The dielectric constants are usually in the range of ($2.2 \leq \varepsilon_r \leq 12$) [3-4]. This paper presents the use of transmission line method to analyze the rectangular micro strip antenna [5]. The operating frequency used for the Rectangular patch antenna array in this paper is 8.29 GHz. RMPA is characterized by its width W, length L and thickness h, as shown in Figure-1.

RMPA, which has been used in this paper, the length L of the patch is usually $0.3333\lambda_o < L < 0.5\lambda_o$, where λ_o is the free-space wavelength. The patch is selected to be very thin such that $t \ll \lambda_o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda_o \leq h \leq 0.05\lambda_o$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

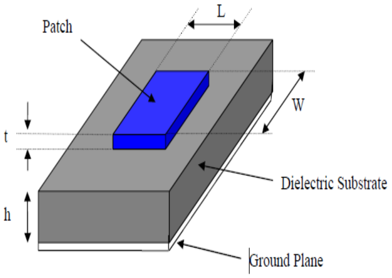

Figure 1. Structure of a rectangular microstrip patch antenna.

2. Design Consideration

We have designed an array of rectangular patch Antennas of the resonant frequency 8.29 GHz. We have employed a patch array antenna structure where we are using Rogers RT/duroid 5880(tm) having ε_r=2.2 as the dielectric. The first patch is fed via a microstrip line of 50 ohms impedance [8]. The array is the replication of the first patch. One side is substrate, backed with the ground on the other side, as can be seen in figure 1.

Microstrip antennas offer several tradeoffs that need to be considered [9]. Because they are manufactured with PCB traces on actual PCB boards, they can be vary, the three essential parameters for the design of microstrip patch antenna are: 1) Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately. 2) Dielectric constant of the substrate (ε_r). A substrate with low dielectric constant (2.2) is selected since it reduces fringing fields 3) Height of dielectric substrate (H): For the microstrip patch antenna the height of the dielectric substrate is critical since the antenna should not be bulky. The transmission line model will be used to design the antenna [7].A microstrip line feed is to be used in this design. The center of the patch is taken as the origin and the coordinates give the feed point location (X_f, Y_f):

2.1 Antenna Design Calculations:

The transmission line model will be used to design the antenna.

2.1.1 Calculation of the Width (*W*): The width of the microstrip patch antenna is given by equation (1)

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon r + 1}{2}}} \tag{1}$$

Here taking Rogers RT/duroid 5880(tm) as the dielectric material used as substrate so, εr as 2.2, by taking a operating Frequency, Velocity of light, c = 3*10^8 m / s, we get width of patch for our desired application as 14.30mm.

2.1.2 Calculation of height of dielectric substrate (H): The equation (2) to determine the height of the dielectric substrate is:

$$H = \frac{0.3c}{\left(2\pi f_{\varepsilon r}\right)^{\frac{1}{2}}} \tag{2}$$

Here again taking Rogers RT/duroid 5880(tm) as the dielectric material used as substrate so, ε_r =2.2, Frequency of operation f_o, Velocity of light, c = 3*10^8 m/s. Taking these values we get height of dielectric substrate as 0.1025mm.

2.1.3 Calculation of Effective dielectric constant (ε_{eff}): Following equation (3) gives the effective dielectric constant as:

$$\varepsilon_{eff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{3}$$

We take the value of ε_r as 2.2 because using Rogers RT/duroid 5880(tm) as substrate. Using the values of W and h as calculated above we find ε_{eff} = 2.5.

2.1.4 Calculation of the Effective length (L_{eff}): Equation below gives the effective length as:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \tag{4}$$

Again taking values ε_{eff} = 2.5, f_o, c = 3*10^8mm We get L_{eff} =12.06mm. Calculation of the length extension (Δ L): Equation (5) below gives the length extension

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{5}$$

Substituting ε_{eff}, W, and H and we get: ΔL=0.4042mm

2.1.5. Calculation of actual length of patch (L): The actual length is obtained by equation (6)

$$L = L_{eff} - 2\Delta L \tag{6}$$

Substituting L_{eff} and ΔL and so we get: L=11.25mm Calculation of the ground plane dimensions (L_g and W_g): The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It is known that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery [1]. Hence, for this design, the ground plane dimensions would be given as:

L_g = 6h + L =16.014mm
W_g= 6h + W=19.064mm.

2.1.6. Determination of feed point location: A microstrip line feed is to be used in this design. As shown in Figure the center of the patch is taken as the origin and the feed point location is given by the co-ordinates (X_f, Y_f) from the origin. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency [6]. Usually it is found practically that feed point is found at one third of the length and width of the patch. And then to get the exact location of the feed point a trial and error method is used, i.e., to compare the return loss (R.L) and select the feed point where the R.L is allowable.

The parameters calculated above are optimized in order to obtain the results.

3. Simulation Results

For the simulation of results, Ansoft High Frequency Structure has been used. A patch antenna with length= 12mm, width=15.69mm and ε_r =2.2 is designed, then the patch array designed is the replica of the single patch. A SRR is then inserted in the microstrip line to reduce the mutual coupling and thereby improve the directive gain.

It should be noted that lower the return loss, the better the antenna radiates. Figure 2 shows the S21 parameter of microstrip line with SRR inserted into it. It provides a peak isolation of -29dB. Figure 3 shows maximum dip at the resonant frequency, and provides return loss of -22.07 dB. Figure 4 shows that a VSWR ≤ 2 is achieved for patch antenna array. From figure 5, we observe that a directive gain of 10.03dB is achieved, by reducing the mutual coupling between the patch elements by the SRR. SRR acts as a filter for the resonant frequency. SRR reduces the surface waves and thereby improves the gain.

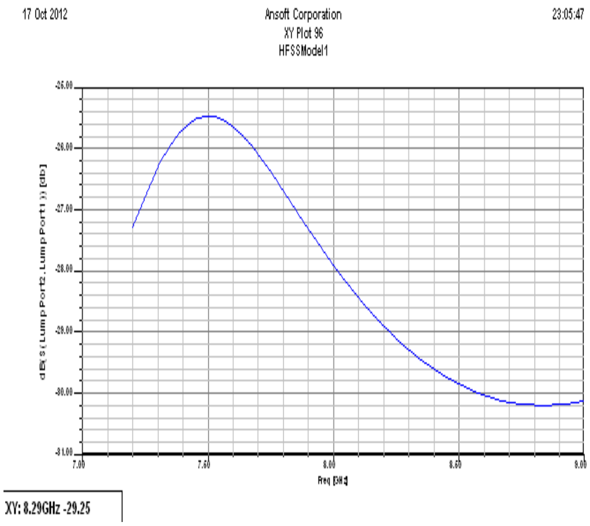

Figure 2. S12 parameter of microstrip line

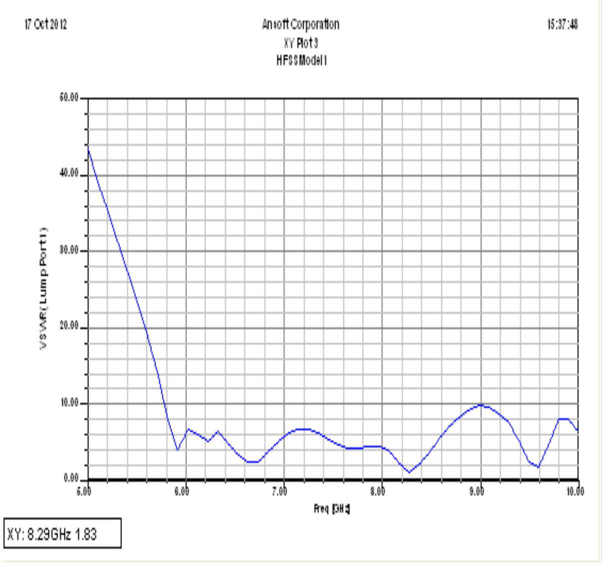

Figure 4. VSWR of patch antenna array with metamaterial

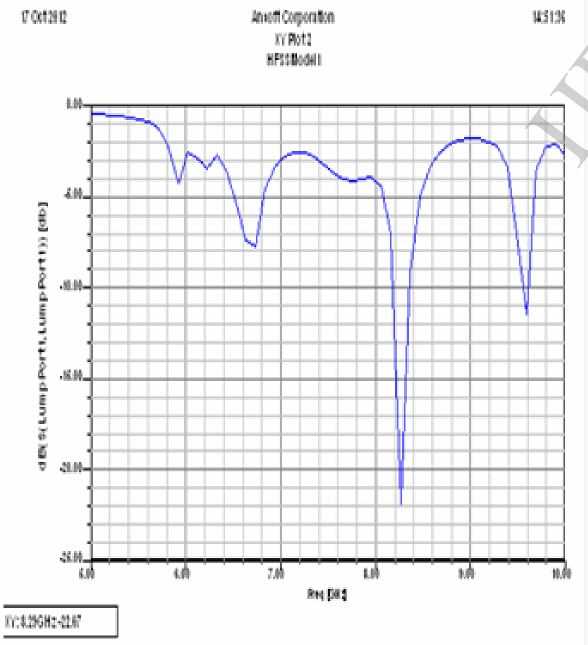

Figure 3. S11 parameter for patch antenna array with metamaterial

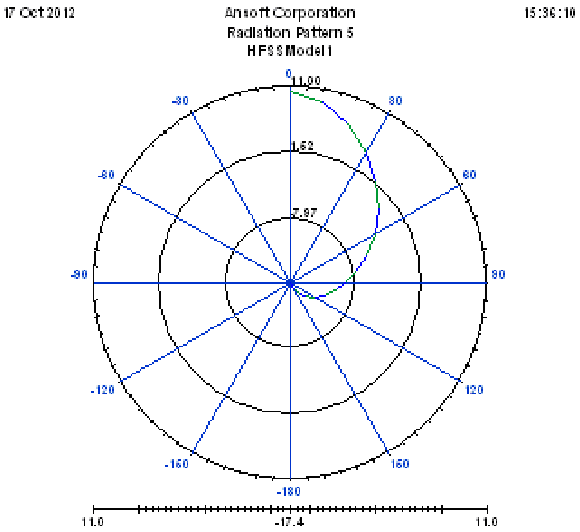

Figure 5. Radiation pattern for directive gain of patch antenna array with metamaterial

Table 1. Effect of patch parameters on antenna performance

Dielectric thickness (h mm)	**Patch Specificat-ion** (mm)	**f_o** (GHz)	**Return losses**	**Direc-tive Gain**
0.794	W=15.69 mm ΔL=.4042 ε_{eff} = 2.5 L=12mm	8.29 GHz	-22.07 dB	10.03 dB

4. Conclusion

The metamaterial resonator has been shown to be an effective insulator. Despite its small size it provided -29 dB of peak isolation. A physically small three-element patch array employing metamaterial insulators demonstrated superdirectivity. For substrate thickness of 0.794mm width 15.69 mm and length 12mm we get a directive gain of 10.08dB, which is much improved in comparison to a single patch antenna. We also know that suppressing mutual coupling as is provided by such insulators allows improvement in beam-steering and anti-jamming null-stearing, and this is another reason to use metamaterial insulators in such arrays. This experiment has shown that metamaterial insulators are effective in the design of compact arrays, and it is expected that they can be found useful for numerous other applications.

REFERENCES

[1] C. A. Balanis, Antenna Theory Analysis and Design. New York: Wiley, 1997, ch.14, pp. 811–876.

[2] R. C. Hansen, Phased Array Antennas New York: Wiley, 1998, ch.7.

[3] A. H. Mohammadian, N. Martin, and D. Griffin, “A theoretical and experimental study of mutual coupling in microstrip antenna arrays,” Transaction IEEE Antennas Propagation, vol. AP- 37, pp. 1217–1223, Oct. 1989.

[4] D. M. Pozar and D. Schaubert, “Scan blindness in infinite phased arrays of printed dipoles,” Trans. IEEE Antennas Propagation, vol. AP-32, pp. 602–610, Jun. 1984.

[5] Y. Rahmat-Samii and H. Mosallaei, “Electromagnetic band-gap structures: Classification, characterization and applications,” in Proceedings IEEE ICAP Symposium, 2001, pp. 560–564.

[6] E. Yablonovitch, “Photonic crystals,” J. Modern Opt., vol. 41, no. 2, pp. 173–194, 1994.

[7] K. Buell, H. Mosallaei, and K. Sarabandi, “Electromagnetic metamaterial insulator to eliminate substrate surface waves,” in IEEE Antennas and Propagation Symposium AP-S Digest, Jul. 3–8, 2005, vol. 2A, pp. 574–577.

[8] K. Buell, H. Mosallaei, and K. Sarabandi, “A substrate for small patch antennas providing tunable miniaturization factors,” IEEE Transaction Microwave Theory Technology, vol. 54, no. 1, pp.135–146, Jan. 2006.

[9] S. Maslovski, P. I. I. K. S. Tretyakov, and M. Kaunisto, “Artificial magnetic materials based on the new magnetic particle: Metasolenoid,” Progress in Electromagnetics Research PIER, vol. 54, pp. 61–81, 2005.

[10] C. L. Dolph, “A current distribution for broadside array which optimizes the relationship between beamwidth and sidelobe level,” Proceedings IRE, vol. 34, no. 6, p. 335, 1946.