

Enhanced Gain Microstrip Patch Antenna by Metamaterial

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Abstract

Microstrip Patch antenna possess a low profile, Planner and conformal structure. Due to its exceptional performance parameters, it is continually attracting the interest of many researchers. This research presents a novel method to improve the gain of patch antenna array by suppressing the surface waves. Composite Split Ring Resonator metamaterial is used to suppress the surface waves. The designed structure of Microstrip patch antenna array is simulated by using High Frequency Structure Simulator.

Index Terms— Microstrip Patch antenna, Composite Split ring resonator, Metamaterial.

1. Introduction

In its most basic form, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Fig (1). The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane.

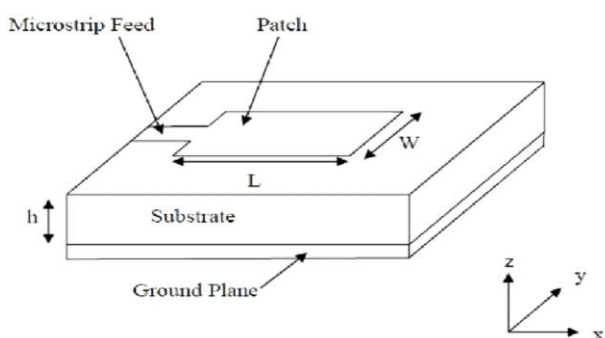


Figure1. Microstrip Patch antenna

The resonant frequency of operation and radiation efficiency of for Patch antenna depends on the dimensions, structure, and material of both patch and substrate. As proposed by research [1-4] For radiating a signal of frequency (f), required patch antenna width (w) is

$$w = \frac{c_0}{2 f \sqrt{\frac{\epsilon+1}{2}}} \text{-----(1)}$$

Here ϵ is the permittivity of the substrate and

$c_0 = 10^8 m/s$ is velocity of light.

The effective optimized permittivity of medium is

$$\epsilon(ef) = \frac{\epsilon+1}{2} + \frac{\epsilon-1}{2} \sqrt{1 + 12 \frac{h}{w}} \text{-----(2)}$$

Here h is substrate height.

Optimized required Patch antenna length (L) is

$$L = \frac{c}{2f\sqrt{\epsilon}} - 2\Delta l \text{-----(3)}$$

Here Δl is extension in length of patch due to available fields.

$$\frac{\Delta l}{h} = .412 \frac{[\epsilon(ef)+.3] \left[\frac{w}{h} + .264 \right]}{[\epsilon(ef)-.258] \left[\frac{w}{h} + .8 \right]} \text{-----(4)}$$

Most of the times gain acquired by single antenna is not sufficient to meet the requirements so we need to uses antenna arrays. When we use antenna arrays the mutual coupling between the patch elements effects the gain of antenna. We are required to reduce this mutual coupling between the elements to improve the performance of antenna by suppressing the surface waves.

Other methods to reduce mutual coupling between array include adding shorting pins in patch array [5] adding a dielectric layer between patch array [6] or adding EBG structures between patch array [7–10]. By using above methods mutual coupling between the arrays can be reduced but it provides a non-planner structure.

In this research a Composite Split ring resonator Metamaterial filter is proposed to suppress the surface waves. Advantages of this filter includes that it provides an overall planar structure. It is the refractive index of CSRR which imparts the filter characteristics. The structure of CSRR is as shown in Fig (2). CSRR structure is complementary of SRR structure and is obtained by extracting the structure from the ground plane. Filtering action of CSRR is due to obtained negative value of permeability at resonant frequency of CSRR. As per the law of optic any material having either negative value of permittivity or permeability do not allow electromagnetic signals to pass through it. The resonant frequency of CSRR is mainly dependent upon the external radius of the CSRR. The resonant wave length is proportional to Ten times the external radius of CSRR.



Figure 2. Complementary Split Ring resonator.

This paper is divided into four sections. The first section presents the Introduction. The second section under the heading Methodology briefly explains the methodology adopted to improve the gain of patch array. Results and discussion section explains the simulation results of the research obtained using High frequency structure simulator. Conclusion of research is presented under heading conclusion. Conclusion is followed by the references used in this research.

2. Methodology

A microstrip patch antenna for resonant frequency of 7.55 GHz is designed by using Rogers RT substrate. Based on design equations of microstrip patch antenna the optimized Patch dimensions are as presented below

Table 1 Dimensions of Patch and Substrate

Substrate	Rogers RT / duriod 58809(tm)
Substrate permittivity	2.2
Substrate Height	.508mm
Patch Length	13.14 mm
Patch Width	15.70 mm

A microstrip patch antenna array of two elements will be designed and simulated by using HFSS.

In order to suppress surface waves between the elements a CSRR filter will be designed and analyzed by using microstrip line. As a rule of thumb, the resonant frequency of CSRR is mainly dependent upon the external radius of the CSRR. The resonant wave length is proportional to Ten times the external radius of CSRR. The validity of CSRR as a filter on desired frequency will be evaluated by using microstrip line. Dimensions of microstrip line for operative frequency of 7.55 GHz are presented below

Table 2. Dimensions of Microstrip line

Substrate	Rogers RT / duriod 58809(tm)
Substrate permittivity	2.2
Substrate Height	.508mm
Length	7.26 mm
Width	1.56 mm

The designed filter will be inserted in the ground of Patch antenna array to suppress the surface waves and to improve the gain of antenna array.

3. Results and Discussion:

The designed patch antenna in HFSS is as shown in Fig 3.

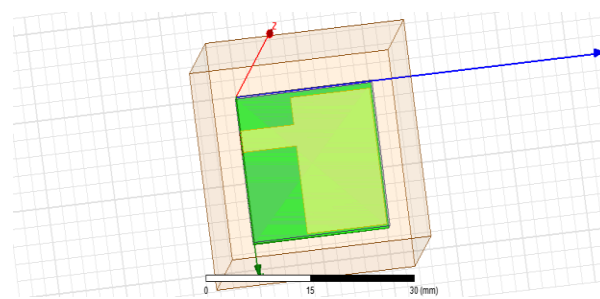


Figure 3. Structure of Patch Antenna

The maximum directive gain of Patch antenna is Designed using HFSS is 4.20 dB as shown in Fig (4).

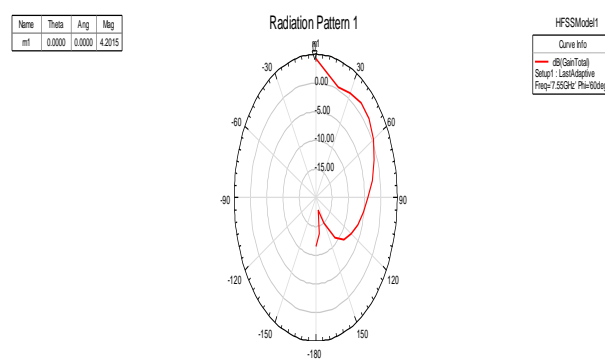


Figure 4. Radiation Pattern of Patch Antenna

Patch array of two elements is designed using HFSS to improve the gain of antenna as shown in Fig 5.

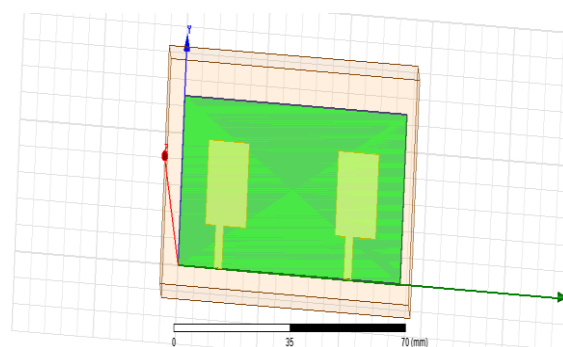


Figure 5. Structure of Patch Antenna Array.

The maximum directive gain of Patch antenna is 6.37 db. as shown in Fig (6). A microstrip line is designed in HFSS for operative frequency of 7.55 GHz. The structure of microstrip line is shown in Fig (7). The transmission parameters of microstrip line are shown in Fig (8). Transmission parameters of line indicate a loss of nearly 0 dB at operative frequency. Transmission line by inserting CSRR in ground plane is shown in Fig (9). The transmission parameters of line obtained by inserting CSRR are represented in Fig (10). The transmission parameter clearly indicates a loss of 35 db at 7.55 GHz. It can be concluded that CSRR is acting as filter for 7.55Hz.

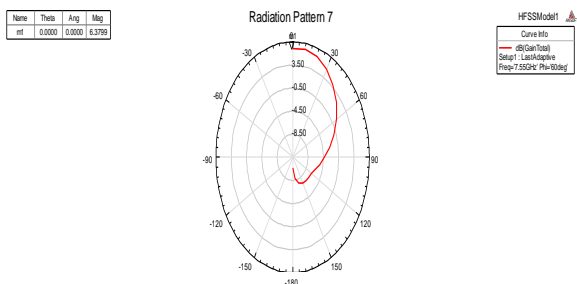


Figure 6. Radiation Pattern of Patch Antenna Array

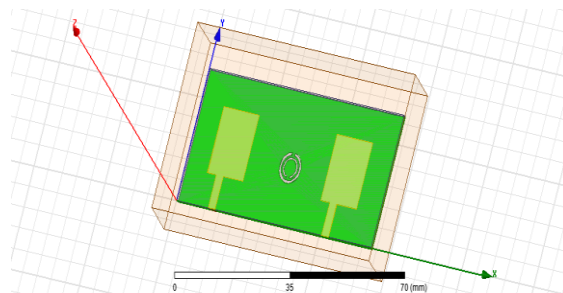


Figure 11. Structure of Patch Antenna Array by incorporating CSRR

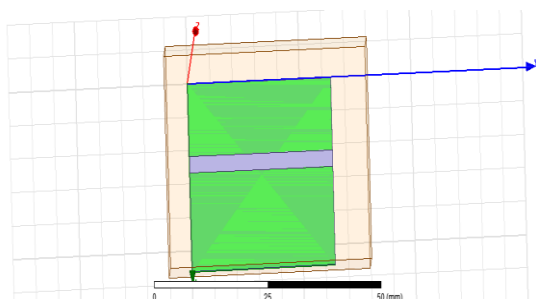


Figure 7. Structure of Microstrip line

The radiation pattern of designed antenna using CSRR is shown in Fig (12).

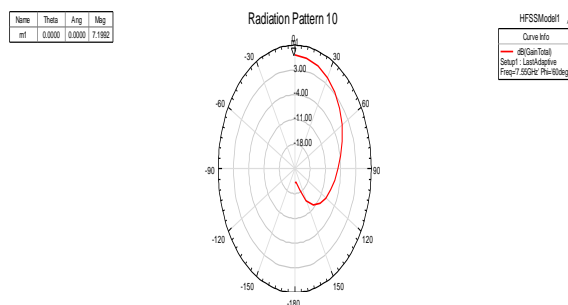


Figure 12 Radiation Pattern of Patch Antenna Array by inserting CSRR

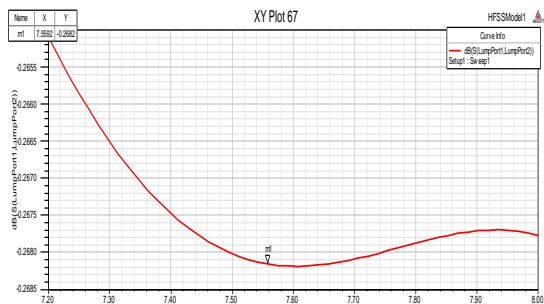


Figure 8. Transmission parameters of Microstrip line

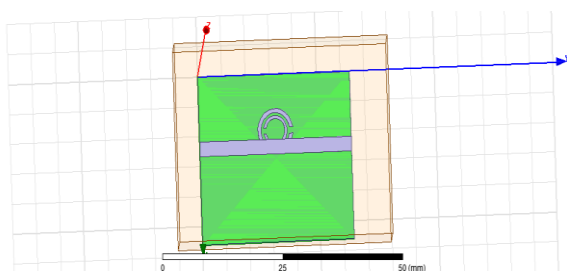


Figure 9. Structure of Microstrip line by inserting CSRR

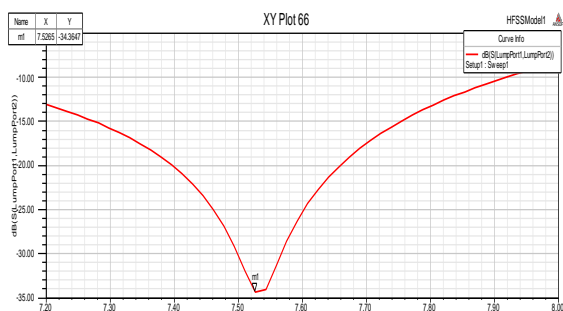


Figure 10. Transmission parameters of Microstrip line by inserting CSRR

This same CSRR is inserted in the ground plane of Patch antenna array as shown in Fig(11).

The maximum directive gain of Patch antenna array is 7.1553 db.

Conclusion

From the results presented above it can be concluded that due to suppression of surface waves by incorporating CSRR in the structure the gain of antenna had improved. Higher gain can be achieved by incorporating a greater number of CSRR in the ground plane.

References

- [1] C. A. Balanis, "Antenna Theory - Analysis and Design," John Wiley & Sons, Second Edition, New York, 1997.
- [2] E. Hammerstad, F.A. bekkadal, Microstrip hand book, LAB report, STF 44 A74169, University of Trondheim, Norway, 1975.
- [3] Monish Gupta, Jyoti Saxena and Anil Vohra "Highly Directive Patch Antenna Using Planar Metamaterial", International Journal of Applied Engineering Research (IJAER)" Volume 4 Number (2009) pp. 89-96.
- [4] James J, Hall P, Wood C, Henderson A (1981) Some recent developments in microstrip antenna design. IEEE Trans Antenna Propag 29(1):124–128.
- [5] Nikolic, M. M., Djordjevic, A. R., & Nehorai, A. (2005). Microstrip antennas with suppressed radiation in horizontal directions and reduced coupling. IEEE Transactions on Antennas and Propagation, 53, 3469–3476.
- [6] Alexopoulos, N., & Jackson, D. (1984). Fundamental superstrate (cover) effects on printed circuit antennas. IEEE Transactionson Antennas and Propagation, 32, 807–816.

- [7] Sievenpiper, D., Lijun, Z., Broas, R. F. J., Alexopolous, N. G. A. A. N. G., & Yablonovitch, E.A.Y.E. (1999). High-impedance electromagnetic surfaces with a forbidden frequency band. *IEEE Transactions on Microwave Theory and Techniques*, 47, 2059–2074.
- [8] Ang, Y & Xuexia, Z. (2002). A novel 2-D electromagnetic band-gap structure and its application in micro-strip antenna arrays. In 3rd international conference on microwave and millimeter wave technology proceedings (pp. 580–583).
- [9] Fan, Y., & Rahmat-Samii, Y. (2003). Microstrip antennas integrated with electromagnetic band-gap (EBG) structures: A low mutual coupling design for array applications. *IEEE Transactions on Antennas and Propagation*, 51, 2936–2946.
- [10] Abedin, M. F., & Ali, M. (2005). Reducing the mutual-coupling between the elements of a printed dipole array using planar EBG structures. *IEEE Antennas and Propagation Society International Symposium*, 2A, 598–601