American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-3, Issue-7, pp-117-124
www.ajer.org
Research Paper Open Access

Gain Enhancement in Microstrip Patch Antennas Using Metallic Rings

Arvind Kumar[1], Mithilesh Kumar[2]
[1,2]*Electronics Engineering Department, University College of Engineering, Rajasthan Technical University Kota, Rajasthan, India)*

Abstract : *This paper presents a novel approach for gain enhancement in microstrip patch antennas using metallic rings. The design forces conversion of the surface wave energy into the space wave energy by scattering of surface waves. The scattering of surface waves created by introducing the metallic ring around the metal patch at a distance of d_1 from the circumference of the metal patch and width of metallic ring is d_2. If another metallic ring is introduced it is at distance of d_3 from the circumference of the first metallic ring and width of it is d_4. Initial values of the metallic rings width d_2 and d_4 are one-quarter of free pace wavelength ($d_2=d_4=4\lambda_0/16$) and spacing between metal rings and metal patch d_1 and d_3 are one-sixteen of free space wavelength ($d_1=d_3=\lambda_0/16$) are selected. Using CST Microwave studio, the results of the patch antenna without metallic rings and patch surrounded by metallic rings are simulated and measured results validates proposed design concept. This microstrip patch antenna operates at the 5.8 GHz frequency suitable for WLAN applications. By this metallic rings approach there is enhancement in the gain of microstrip patch antenna about 6.7 dB as compared to conventional one (without metallic rings).*

Keywords : *Gain; Microstrip Patch Antennas; Return Loss; Surface waves.*

I. INTRODUCTION

Microstrip patch antennas is most widely used in recent wireless communications devices because of some advantageous features such as small size and light weight, cost effective, compact and planner structure, easy interconnection with solid-state devices. The microstrip patch antennas have some drawbacks like somewhat lower gain limited to 4-8dB, surface wave losses [1] when substrate thickness >1mm and narrow bandwidth. Several techniques are introduced to improve these disadvantages. The performance of microstrip patch antennas in terms of gain and directivity is degraded by surface wave losses, dielectric losses and conductor losses. Over the years a lot of work is carried out to overcome these three types of losses dielectric and conductor losses is minimized by using better quality of the substrate and conducting materials. Surface wave losses is reduced by using high impedance surfaces such as electromagnetic [2] and photonic band gap structures [3] that allow and forbid the electromagnetic waves in certain frequency band. Some other methods that reduces the surface wave losses are by using hybrid substrates [4], by using superstrates [5], surface mounting horn [6] etc. but disadvantageous features of these techniques is fabrication difficulties because these techniques requires a large number of holes and vias. In this paper we introduce a novel approach for gain enhancement in microstrip patch antennas by suppressing surface wave propagation in the lateral directions. Metallic rings are placed coplanar to radiation patch so microstrip patch antenna design by metallic rings approach for gain enhancement is very simple in construction as compared to previous gain enhancement techniques.

II. PROPOSED ANTENNA DESIGN

When electromagnetic waves incident on the interface that have small dimensions as compared to incident wave then EM waves are scattered from that interface [7-9], scattered energy radiate in all directions and some of in the directions of incident wave if this energy combined with incident wave either in phase or out of phase causes constructive or destructive interferences and rest of scattered energy that is not combined is may feedback to microstrip cavity and patch reradiate this energy. If this concept is applied to design of microstrip patch antennas by placing metallic rings around the radiation patch to scatter the surface waves. Scattered energy is converted into the space wave energy and enhances the gain of microstrip patch antennas. The geometry of proposed design is shown in the Fig. 1. It is shown that radiation patch on the top of grounded dielectric substrate and it is surrounded by two metallic rings. Metallic rings are in the same plane as

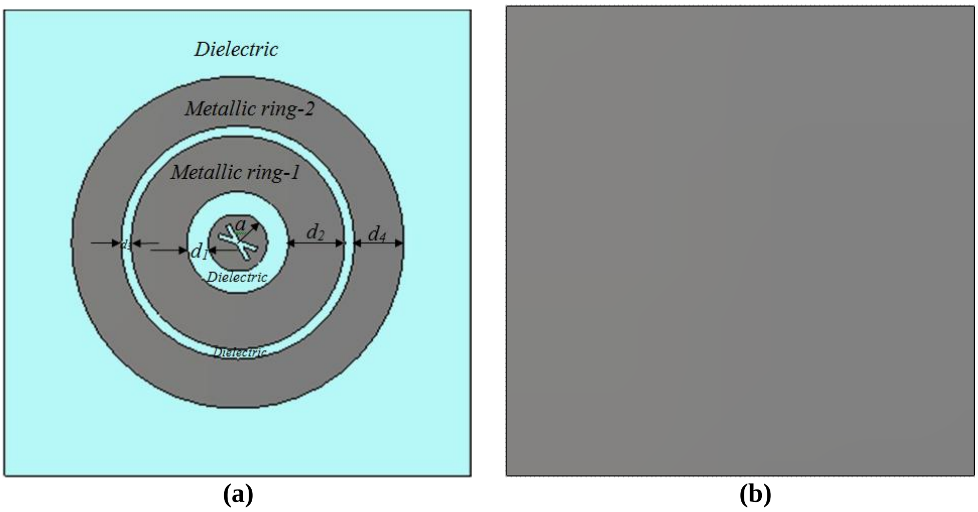


Figure 1. (a) Top view (b) Bottom view of proposed antenna, substrate and ground plane size is 100×100 mm^2 and a=6.3mm.

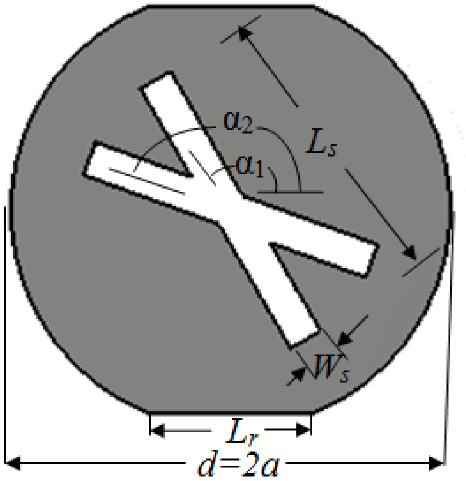


Figure 2. Geometry of circular microstrip patch antenna. Design frequency 5.8 GHz and L_s=8.6 mm, W_s=1 mm $\alpha_1=60^o$, $\alpha_2=120^o$, L_r=4.62 mm, d=12.6mm.

radiation patch and thickness of metallic rings is also same as radiation patch is 0.01mm. The shape of metallic rings depends upon the shape of microstrip patch (circular, square, rectangular etc.). First metallic ring is at d_1 distance from the circumference of metal patch and having width d_2. Second metallic ring is at d_3 distance from the circumference of first metallic ring and having width d_4. Initial values of the metallic rings width d_2 and d_4 are one-quarter of free pace wavelength ($d_2=d_4=4\lambda_0/16$) and spacing between metal rings and metal patch d_1 and d_3 are one-sixteen of free space wavelength ($d_1=d_3=\lambda_0/16$) are selected. Values of d_1, d_2, d_3, d_4 are optimized accordingly that satisfy the maximum gain as a criterion. Optimized values $d_1=1.425\lambda_0/16$, $d_2=3.716\lambda_0/16$, $d_3=0.652\lambda_0/16$ and $d_4=3.283\lambda_0/16$ that are used in simulation and fabrication of proposed design. A parametric variation is illustrated in the end of this paper to find out the optimized values.

III. GAIN AND BANDWIDTH

In this microstrip patch antenna design, a circular microstrip patch [10] designed on FR-4 substrate (relative permittivity of ε_r=4.1) with thickness 1.5 mm. Geometry of circular patch shown in Fig. 2. There are two diagonal slots that provide good impedance matching. The proposed design is simulated using CST Microwave studio [12] and results for both antennas are shown in the same graph for comparison. The S_{11} characteristic is shown in Fig. 3. Dashed line is for antenna-1 (circular patch without metallic rings) and solid line for antenna-2 (circular patch with metallic rings). E-plane radiation pattern of gain for both antennas is shown in Fig. 4, dashed line for circular microstrip patch without metallic rings and solid line for circular microstrip patch with metallic rings at design frequency 5.8 GHz. From Fig. 4 it is observed that antenna-2 (patch with metallic rings) have more directional radiation pattern as compared to antenna-1 (patch without

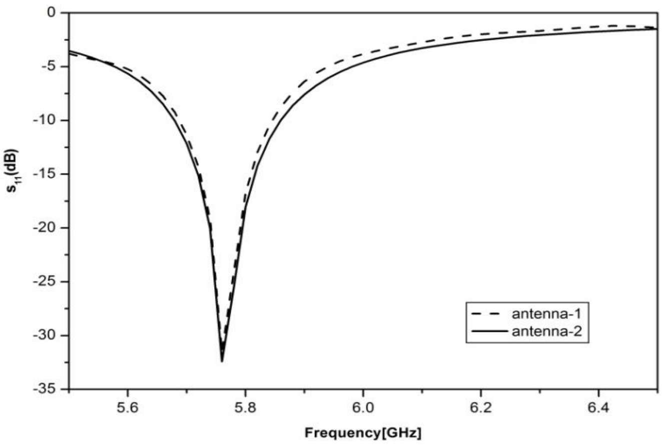


Figure 3. Simulated results of S_{11} of circular patch without metallic ring (dashed line) and with metallic ring (solid line).

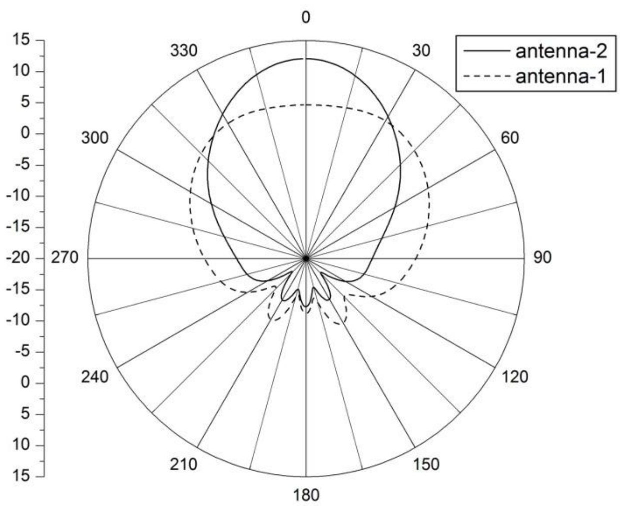


Figure 4. Radiation pattern (in decibels) for circular patch without metallic rings (dashed line) and circular patch with metallic rings (solid line).

metallic rings). Circular patch without metallic rings attain 5.5 dB gain at 5.8 GHz and circular patch with metallic rings attains 12.2 dB gain at same frequency 5.8 GHz. Proposed design also have same radiation pattern of gain in H-plane. So there is enhancement of gain in both E and H planes about 6.7 dB at 5.8 GHz by using metallic rings. Fig. 5 shows electric field intensity on the top surface of both antennas and it can be observed that field intensity in antenna-2 is higher as compared to the antenna-1 due to metallic rings. The normalized E-field intensity in the substrate for both antennas from the

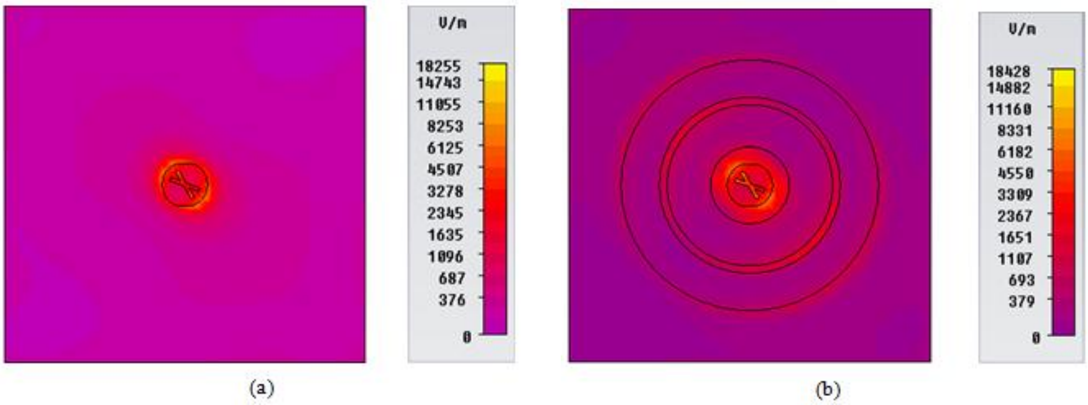


Figure 5. Electric field intensity on the top surface of the circular microstrip patch, metallic rings and substrate. (a) antenna-1 (without metallic rings) (b) antenna-2 (circular patch surrounded by metallic rings).

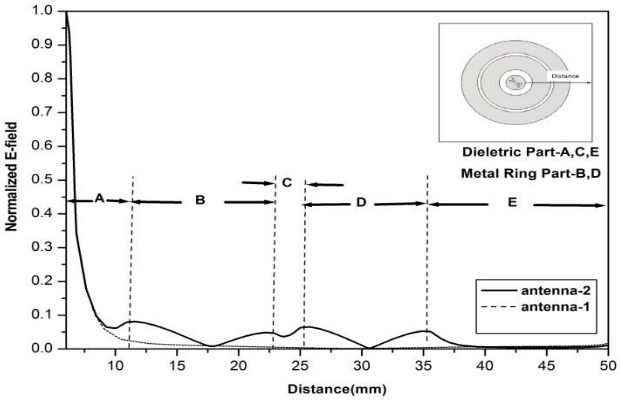


Figure 6. E-field normalized magnitude in the substrate for circular patch without metallic rings (dashed line) and with metallic rings (solid line).

edge of the radiation patch to the end of the substrate is shown in Fig. 6. Dashed line is for patch without metallic rings and solid line for patch surrounded by metallic rings. It can be observed that the field intensity on surface of antenna-2 and in the metallic ring part is higher than the field intensity in the antenna-1 or without metallic ring part and as seen from the graph field intensity is maximum in the radiation patch and it decreases as move away from it, but it gets peak at the edges of metallic rings this shows the EM-waves are scattered from the metallic ring and surface wave is converted into space waves and this is the reason of gain enhancement.

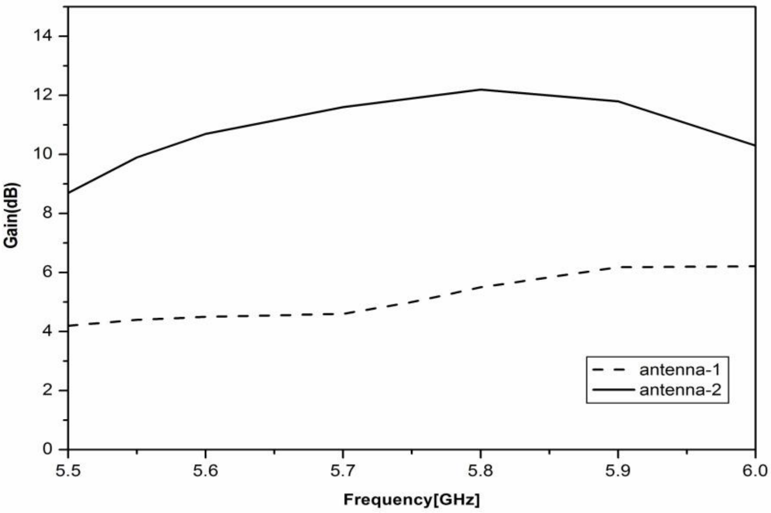
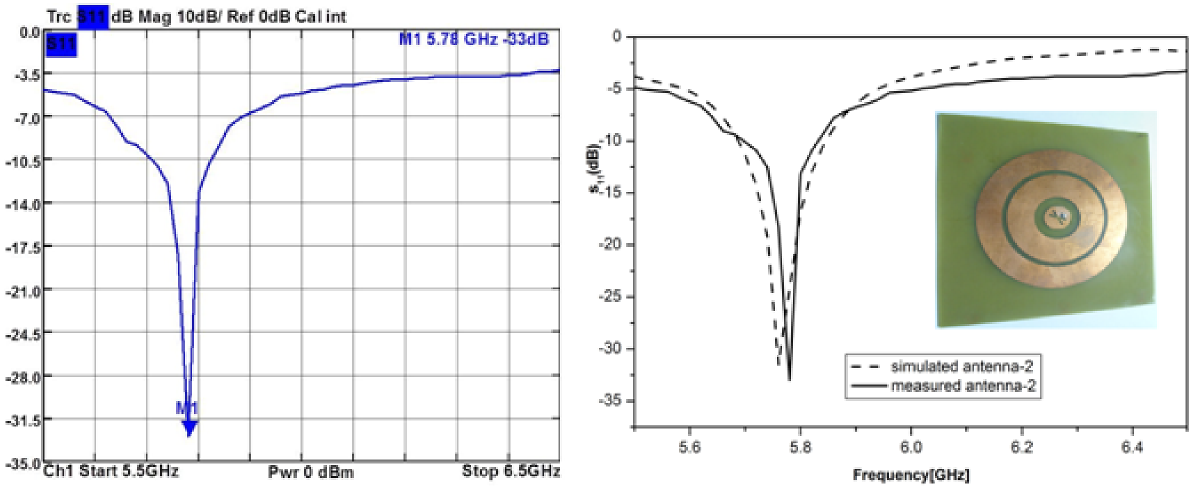


Figure 7. Frequency response graph of the gain for circular patch without metallic rings (dashed line) and with metallic rings (solid line).

Electric field intensity of antenna-2 is eight to nine times higher as compare to antenna-1and from the several simulations it is observed that whenever there is higher field intensity, antenna exhibits higher gain. Frequency response graph of the gain is shown in the Fig. 7, circular patch without metallic rings is shown by dashed line and for circular patch with metallic rings is shown by solid line and the antenna-2 (patch with metallic rings) achieves average gain of 10.88 dB in the frequency range of 5.5–6 GHz and in the same frequency range circular patch without metallic ring have average of 5.2 dB gain. Hence patch with metallic ring have higher average gain as compared to patch without metallic ring. In order to validate proposed design concept, proposed antenna was fabricated and photograph of fabricated antenna is shown in Fig. 8. Measured results of S_{11} is shown in Fig. 9, simulated and measured results are shown in the same graph for comparison and there is marginal shift in resonant frequency 5.75 GHz to 5.78 GHz in measured results in comparison of simulated results, so there is good agreement between measured and simulated results.

(a) (b)

Figure 8. Photograph of fabricated antenna (a) Front (b) Back view



(a) (b)

Figure 9. Measured results (a) VNA screen output (b) Comparison of measured and simulated results

IV. MAXIMUM GAIN

The parametric variation in the metallic ring width d_2 and d_4, and its spacing d_1 and d_3 were performed to determine the optimal values of d_1, d_2 and d_3, d_4 using the maximum gain as a criterion. The gain was calculated first for values of d_1 and d_2 from 0.0625λ_0 to 0.25 λ_0 in steps of 0.0625λ_0. Fig. 10 depicts the maximum gain as a function of d_1 and d_2 and graph shows that gain was calculated as function of d_1 for different values of d_2. From the Fig. 10 it is observed that the maximum gain is achieved when d_2 equals four times of the one by sixteen of free space wavelength and it flat for all values of d_1 so choose the minimum value of d_1, d_1 equals to one by sixteen of free space wavelength. So optimal values are d_1=λ_0/16 and d_2=4λ_0/16 that shows maximum gain. Values of d_1 and d_2 can be optimized accordingly that satisfy maximum gain as criteria.

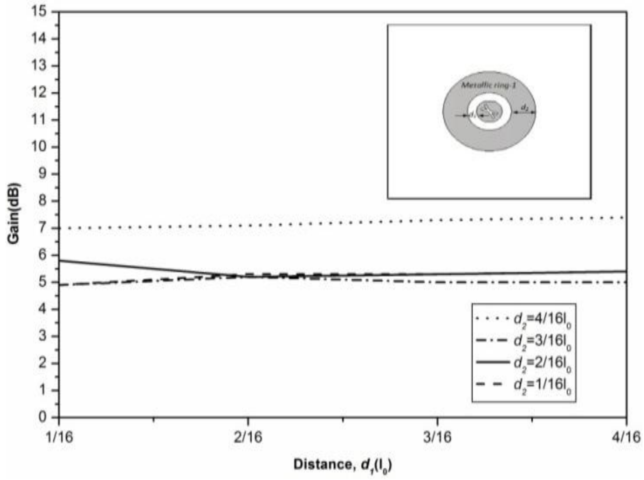


Figure 10. Maximum gain for as a function of d_1 and d_2 (d_1 and d_2 are function of free space wavelength λ_0=l$_0$).

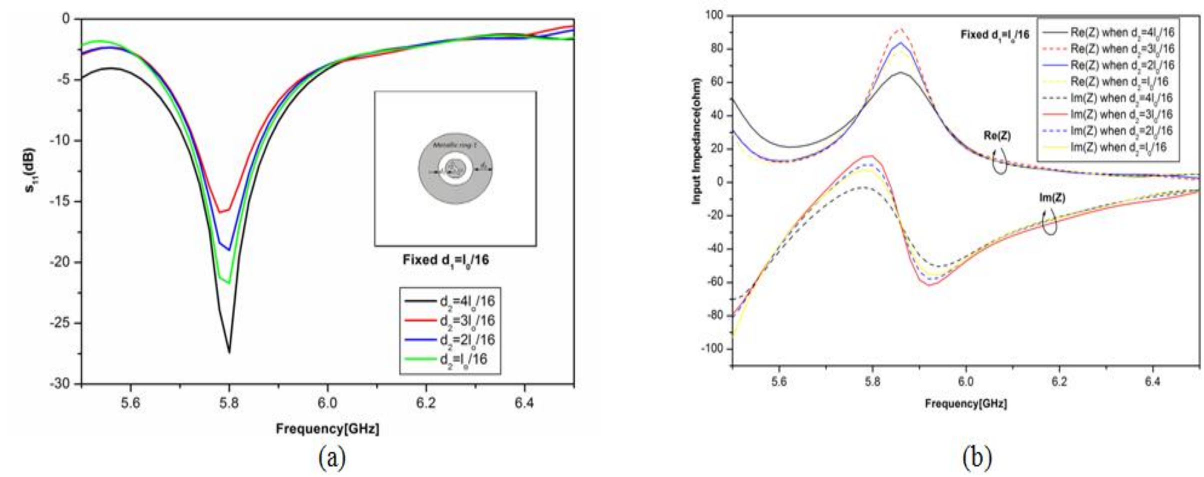


Figure 11. (a) S_{11} Graph (b) Impedance Graph for fixed value of d_1 and variation in d_2 (d_1 and d_2 are function of free space wavelength λ_0=l$_0$).

Fig. 11(a) shows S_{11} graph for fixed value of d_1 and variation in d_2 from 0.0625λ_0 to 0.25 λ_0 in steps of 0.0625λ_0. Fig. 11(b) shows input impedance graph for fixed value of d_1 and variation in d_2 from 0.0625λ_0 to 0.25 λ_0 in steps of 0.0625λ_0.So fixed d_1 and d_2 at d_1=λ_0/16 and d_2=4λ_0/16 and another metal ring is placed around the first metal ring at distance of d_3 and width d_4 and to find the optimal values of d_3 and d_4 a parametric variation is performed satisfying maximum gain as a criteria. The gain was calculated for values of d_3 and d_4 from 0.0625λ_0 to 0.25 λ_0 in steps of 0.0625λ_0. Fig. 12 shows the maximum gain as a function of d_3 and d_4 and fixed d_1 and d_2 at d_1=λ_0/16 and d_2=4λ_0/16, graph shows that gain was calculated as function of d_3 for different values of d_4. From the Fig. 12 it is observed that the maximum gain is achieved when d_4 equals three times of the one by sixteen of free space wavelength and it almost flat for all values of d_3 so choose the minimum value of d_3, d_3 equals to one by sixteen of free space wavelength. So optimal values are d_3=λ_0/16 and d_4=3λ_0/16 that shows maximum gain. Values of d_3 and d_4 can be optimized accordingly that satisfy maximum gain as criteria.

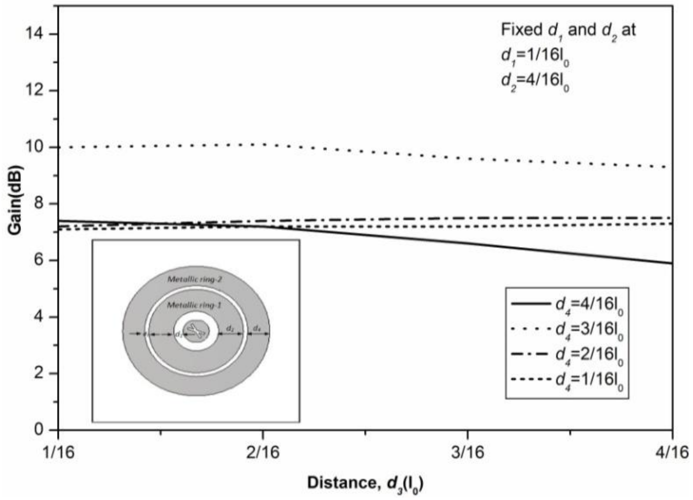
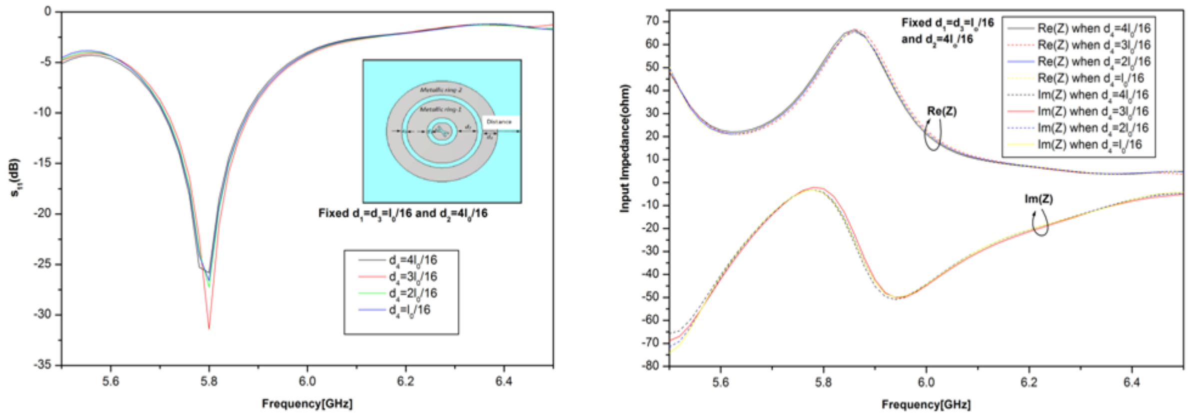


Figure 12. Maximum gain for as a function of d_3 and d_4 (d_3 and d_4 are function of free space wavelength λ_0=l0).



(a) (b)

Figure 13. (a) S_{11} Graph (b) Impedance Graph for fixed value of d_1, d_2, d_3 and variation in d_4 (d_1, d_2, d_3 and d_4 are function of free space wavelength λ_0=l0).

Fig. 13(a) shows S_{11} graph for fixed value of d_1, d_2, d_3 and variation in d_4 from 0.0625λ_0 to 0.25 λ_0 in steps of 0.0625λ_0. Fig. 13(b) shows impedance graph for fixed value of d_1, d_2, d_3 and variation in d_4 from 0.0625λ_0 to 0.25 λ_0 in steps of 0.0625λ_0.

So optimal values are found metal rings width are $d_2=4\lambda_0/16$, $d_4=3\lambda_0/16$ and spacing is $d_1=d_3=\lambda_0/16$. It is observed from several simulations that by reducing d_1, and d_3 maximum of 13 dB gain is obtained from two metal rings around the metal patch. Gain is also increases by increasing number of metallic rings there is no limitations for number of rings and shape of ring its shape square, circular depends on the shape of patch but its function is to reduce the surface waves. As we know that surface waves are decreases exponentially in the substrate, so by increasing number of rings more than two or three there is no impact on the maximum gain. Microstrip patch antenna design by metallic ring approach is very simple in construction as compared with the state of art.

V. CONCLUSION

We conclude that a patch with metallic ring causes the enhancement in the gain as compared with the patch without metallic ring. From the graphs presented in this paper it is observed that there is enhancement of 6.7 dB in the gain when patch is surrounded by metallic ring as compared with the patch without metallic ring. Analysis of the fields in the substrate shows that surface wave are scattered from metallic ring and convert into the space waves. A parametric study illustrated that shows the maximum gain was obtained when d_1, d_3 are near one by sixteen of the free-space wavelength and d_2 is near four times one-sixteen of free space wavelength d_4 are near three times one-sixteen of free space wavelength.

REFERENCES

[1] R. B. Waterhouse, Microstrip Patch Antennas—A Designer's Guide. Boston, MA: Kluwer Academic Publishers, 2003, ch. 4.

[2] D. Sievenpiper, L. Zhang, R.F. Jimenez Broas, N. G. Alexopoulos, and E. Yablonovitch, "High-impedance electromagnetic surfaces with a forbidden frequency band", IEEE Trans. Microwave Theory Techn., vol. 47, pp. 2059-2074, Nov. 1999.

[3] Gonzola and De Maagt and sorola "Enhanced patch-antenna performance by suppressing surface waves using photonic-bandgap substrates" IEEE Trans. Microwave Theory Techn., vol. 47, pp. 2131-2138, Nov. 1999.

[4] A. Rivera-Albino and C.A. Balanis "Gain Enhancement in Microstrip Patch Antennas Using Hybrid Substrates" IEEE Antennas and Wireless Propagation Letters, vol. 12, pp. 476-479, April 2013.

[5] Hussein Attia and Leila Yousefi "High-Gain Patch Antennas Loaded With High Characteristic Impedance Superstrates" IEEE Antennas And Wireless Propagation Letters, vol. 10, pp.858-861, August 2011.

[6] P. Kumar, D. Batra, and A. K. Shrivastav, "High gain microstrip antenna capacitive coupled to a square ring with surface mounted conical horn," Int. J. Electron. Commun. Technol., vol. 1, no. 1, pp. 7–9, Dec. 2010.

[7] Yong H. Cho., Cheolsig Pyo and Jaeick Choi "Gain Enhancement of Microstrip Patch Antenna Using Parasitic Metallic Bar" IEEE AP-S. vol. I, pp. 728 -731, 2003.

[8] C. S. Lee. V. Nalbandian and F. Schwcring. "Gain enhancement of a thick microstrip antenna by suppressing surface waves," IEEE AP-S. vol. I, pp. 460 -463, 1994.

[9] C. Balanis, Advanced Engineering Electromagnetics, 2nd ed. NewYork, NY, USA: Wiley, 2012.

[10] H. Boutayeb, T. Djerafi, and K. Wu, "Gain enhancement of a circularly polarized microstrip patch antenna surrounded by a circular mushroom-like substrate," in Proc. EuMC, Sep. 2010, pp. 257–260.

[11] F. Tinoco-S., D. C. Nascimento, R. Schildberg, and J. C. da S. Lacava "Analysis and Design of Rectangular Microstrip Antennas for Educational Purposes" IEEE Antennas and Propagation Magazine, vol. 53, No.1, February 2011.

[12] CST. Computer simulation technology microwave studio 2011. [Online]. Available: http://www.cst.com