Gain Enhancement in Microstrip Patch Antennas using Metallic Ring at 10 GHz

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ABSTRACT

A microstrip patch antenna is designed that have metallic ring coplanar to radiation patch for gain enhancement is proposed. The design forces conversion of the surface wave energy into the space wave energy by the scattering of surface waves from metallic ring. The metallic ring is placed around the metal patch at a distance of d_1 from the edges of the metal patch and width of metallic ring is d_2. Using CST Microwave studio, the results of the patch antenna without metallic ring and patch surrounded by metallic ring are simulated and compared. The proposed microstrip patch antenna operates at the 10.5 GHz frequency. By this proposed antenna design there is enhancement in the gain of microstrip patch antenna about 185% as compared to conventional one (without metallic ring).

Keywords

Gain, Microstrip Patch Antennas, Return Loss, surface waves

1. INTRODUCTION

The microstrip patch antennas is most widely used in wireless communication applications and the demand for its application has been increasing rapidly, especially within the past few decades because of the microstrip antennas have light weight, small size, low profile, cost effective, planner structure, compact and easy fabrication. There is some disadvantages of microstrip patch antennas such as low gain and narrow bandwidth, surface wave excitation [1]. Several techniques are used to remove these disadvantages.

In most common form of microstrip patch antennas metal patch is on the top of grounded dielectric substrate and when antenna is energized it radiates EM waves in the all directions and the EM waves that travel in the substrate is known as surface waves and loss due to these surface wave is known as surface wave losses, this is main loss associated with microstrip patch antennas that reduce the gain of microstrip patch antennas. Other losses such as conductor on dielectric losses can be minimized using good quality conducting material and substrate. Several approaches are introduced to overcome the surface wave losses such as EBG and PBG [2]-[4] structures that allows the emission and propagation of EM wave in the certain frequency band. The other methods of gain enhancement in microstrip patch antennas are array of antennas [5]and by using superstrates [6], hybrid substrates [7], surface mounted horn [8] etc. but main drawback associated with these methods is complexity of construction.

In this paper we introduce novel approach for suppression of surface waves in the lateral directions by introducing metallic rings coplanar to radiation patch for gain enhancement in the microstrip patch antennas. The proposed antenna is very simple in construction.

2. PROPOSED ANTENNA DESIGN

We know that when EM waves are scattered when incident on a interface that have small dimensions as compared to the incident EM wave [9]-[11]. If this concept is applied to the design of microstrip patch antennas, then this can cause improvement in the performance of microstrip patch antenna in terms of gain and bandwidth. This interface is created by placing metallic ring around the radiation patch. The surface waves are scattered from metallic ring and convert into the space waves so in this proposed antenna design surface wave radiation in the lateral direction is reduced. So by the metallic ring approach surface wave losses are minimized and surface wave energy is converted into space wave energy. Thus minimizing surface wave losses there is enhancement in gain of microstrip patch antenna.

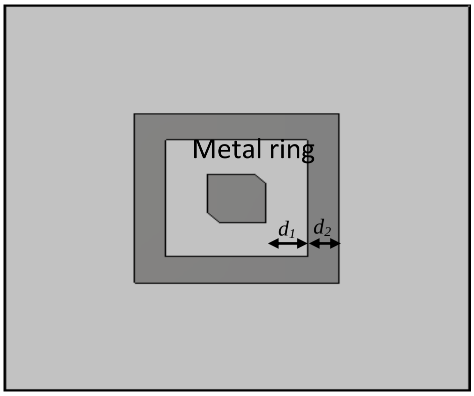


Fig 1: Top view of proposed antenna, including the dielectric substrate, a metallic ring, patch, and substrate size is 100×100 mm^2.

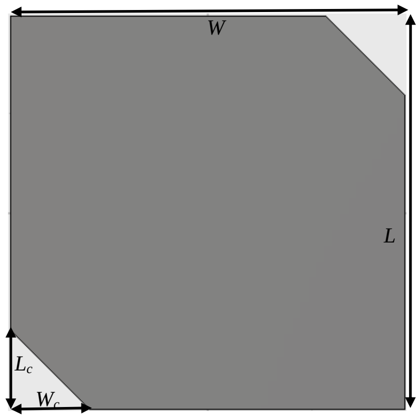


Fig 2: Geometry of the square microstrip patch antenna. For a design frequency of 10.5 GHz: L=W=10 mm, W_c=L_c=3 mm.

The geometry of the proposed antenna is shown in Fig. 1. As can be seen from the figure, that coaxial-feed square metal patch is surrounded by a square metal ring and it is coplanar to radiation patch. The metallic ring is placed around the metal patch at a distance of d_1 from the edges of the metal patch and width of metallic ring is d_2. Initial values of d_1 and d_2 are one-quarter of free pace wavelength (d_1=d_2=4λ_0/16). The values d_1 and d_2 are optimized as metal ring is at a distance of one-quarter of free space wavelength (d_1=4λ_0/16) from edges of the square patch and width of three times one-sixteen of free space wavelength (d_2=3λ_0/16) and values of d_1 and d_2 can be further optimized accordingly that enhance the gain of microstrip patch antenna.

3. GAIN AND BANDWIDTH

In this proposed antenna, a coaxial-feed square patch antenna was designed using a FR-4 substrate (relative permittivity of ε_r=4.1) with thickness of h=1.5 mm and operating frequency of 10.5 GHz, with dimensions of square patch L=W=10 mm. Patch is cut at diagonal edges for circular polarization.

Using CST Microwave studio [13], the results of the patch antenna without metallic rings named as antenna-1 and metal patch surrounded by metallic ring named as antenna-2 are simulated and results are shown in the same graph for comparison. Fig. 3 shows S_{11} graph for antenna-1 (dashed line) and antenna-2 (solid line) and Fig. 4 radiation pattern (in decibels) at design frequency of 10.5 GHz for antenna-1 (dashed line) and antenna-2 (solid line).

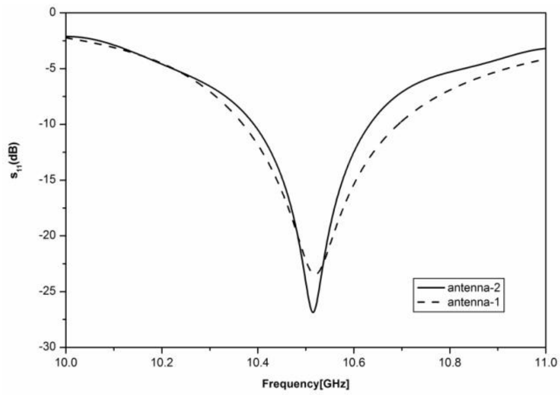


Fig 3: S_{11} graph for square patch without metal ring (dashed line) and with metal ring (solid line).

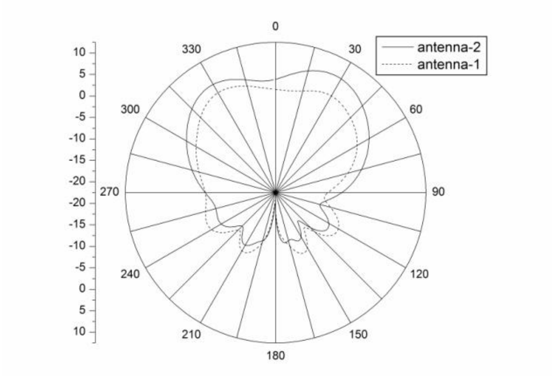


Fig 4: Radiation pattern (in decibels) for antenna-1 (dashed line) and antenna-2 (solid line) at 10.5 GHz.

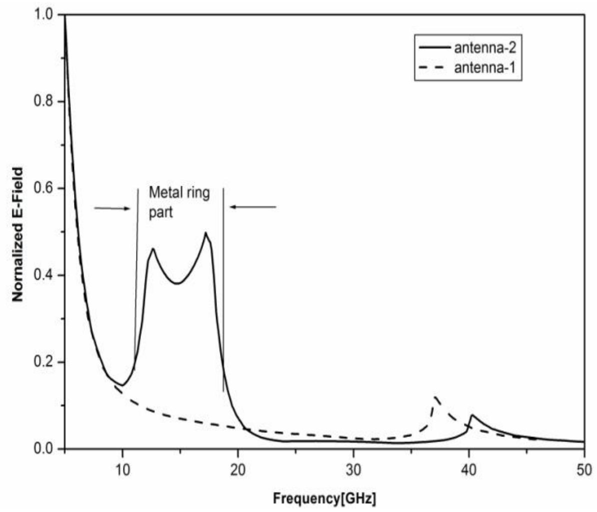
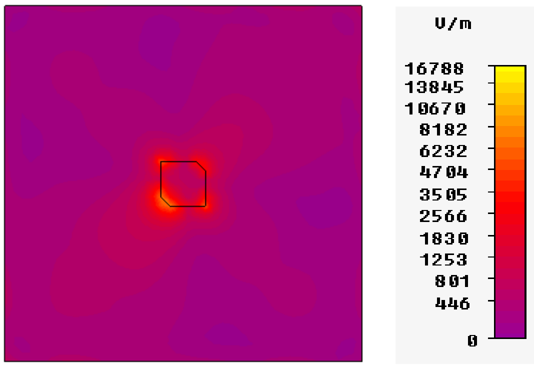
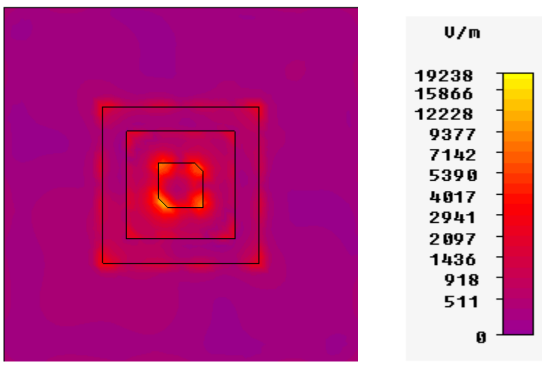


Fig 5: E-field normalized magnitude on the top surface of substrate for square patch without metal ring (dashed line) and with metal ring (solid line).



(a)



(b)

Fig 6: Electric field magnitude on the surface of the square microstrip patch and substrate, metal ring. (a) antenna-1 (b) antenna-2

Fig. 4 shows that there is enhancement in the gain of microstrip patch antenna when it is surrounded by metallic ring. For antenna-1 we achieved 4.4 dB gain and for antenna-2 we achieved 8.1 dB gain at resonant frequency in the both E-plane and H-plane. So two-dimensional radiation pattern shows there is enhancement in gain about 3.7 dB by using metallic ring as compared to square patch without metallic ring.

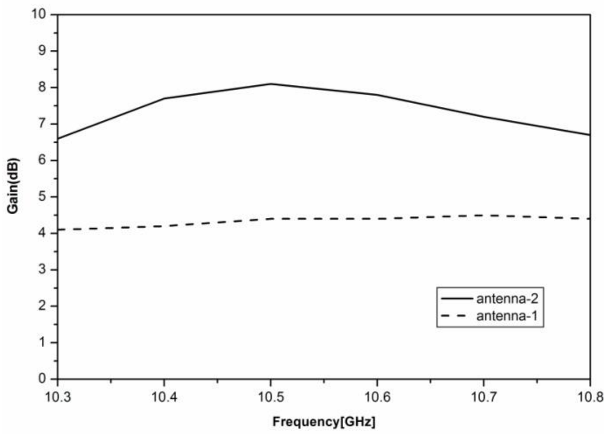


Fig 7: Frequency response graph of gain for antenna-1 (dashed line) and antenna-2 (solid line)

The normalized field intensity on the surface of the substrate from the edge of the patch antenna to the end of the substrate is shown in Fig. 5. It can be observed that the field intensity on top 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 metal ring this shows the EM-waves are scattered from the metallic ring. It is observed metallic ring part have higher intensity antenna exhibits higher gain and metallic ring part exhibits ten to fifteen times higher intensity as compared to dielectric part. From the several simulations it is observed that whenever metallic ring have higher intensity antenna exhibits higher gain. Fig. 6 shows a top view of the E -field intensity in the two antennas and it can be observed that field intensity in antenna-1 is low as compared to the antenna-2 which exhibits higher field intensity due to metallic ring and this is reason of gain enhancement. Frequency response graph of the gain for square patch without metallic ring is shown by dashed line and for square patch with metallic ring is shown by solid line are shown in the Fig. 7. The antenna-2 (patch with metallic ring) achieve average gain of 7.35 dB in the frequency range of 10.3–10.8 GHz and in the same frequency range square patch without metallic ring have average of 4.33 dB gain. Hence patch with metallic ring have higher gain as compared to patch without metallic ring.

4. CONCLUSION

We conclude that a patch with metallic ring causes the enhancement in the gain of microstrip patch antenna. From the graphs presented in the paper it is observed there is enhancement in 3.7 dB in the gain by using metallic ring as compared to the patch without metallic ring.

Analysis of the electric fields on the top of the the substrate shows that surface wave are scattered from metallic ring and convert into the space waves.

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