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Increasing Microstrip Patch Antenna Bandwidth by Inserting Ground Slots

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Abstract

Microstrip patch antenna (MPA) is widely implemented in different communication systems. One of the main disadvantages of MPA which limits its applications is its narrow bandwidth. In this paper I enhanced the bandwidth of MPA by inserting multiple slots in its ground plane. I used FR-4 substrate to design this antenna. The dimensions of this antenna are 59 mm and 79 mm. The dielectric constant is 4.4 and the height is 1.6 mm. I inserted up to 15 slots in ground plane with 1mm width. The spacing between slots is 3 mm. I investigated two designs. In the first design, slots were arranged in parallel to the feeding line. In the second one, slots were arranged horizontally to the feeding line. The main objective of this paper is to design and simulate MPA suitable for wide number of applications. Antenna bandwidth improvement is 18%. All the simulations were obtained by using HFSS simulator.

Keywords

Microstrip Patch Antenna, Bandwidth, Ground Slots, HFSS Simulator

1. Introduction

The main objective of communication systems is to transmit information bearing signals from transmitter to the receiver via communication channel. The antenna is used in both transmitting and receiving parts to convert voltage or current into electromagnetic signals and *vice versa*. MPA are commonly used in different Communication systems due to their small size, high gain and their omnidirectional radiation pattern. MPA are used in different applications like wireless communication including mobile communication. They are also used in computer links, remote controls, satellite communication and radar systems. One of their disadvantages is narrow bandwidth. MPA usually consists of a radiating patch which is made of conducting material such as gold or copper. It can take any possible shape such as rectangular, triangular, square, or circle [1]. The radiating patch and the feed lines are usually inserted on the dielectric substrate as shown in **Figure 1**.

One of the limitations of this type of antennas is the narrow bandwidth. A lot of techniques are used to improve its performance like Shorted Patch [2], Stacked Shorted Patch [3], Slot-Loading Technique [4] and Slotted Ground Plane [5]. More techniques are continuing to appear in order to make the performance of the MPA better and better.

In [6] authors inserted slots into MPA to improve its bandwidth. It demonstrates the design of slotted microstrip antenna on a substrate of thickness 1.588 mm that gives wideband characteristics. The illustrated patch antenna provides bandwidth enhancement compared to antenna without slots of the same physical dimensions. The simulation carried using IE3D simulator.

In [7] three different geometry shape, the U, E and H were developed from a rectangular patch of width (W) = 32 mm and length (L) = 24 mm. Bandwidth improvement was 4.81% for 100 MHZ, 28.89% for 610 MHz, 9.13% for 630 MHz and 9.13% for110 MHz.

In [8] authors improved antenna bandwidth by 25% by inserting slots on ground plane and stacked patch supported by wall. This design doesn't affect the frequency of operation. In [9] Slots of different shapes such as triangular or rectangular were placed on the ground plane under the feed line of the radiator for bandwidth increasing and impedance matching.

2. Antenna Design Procedure

We are going to design rectangular microstrip patch antenna with and without slots on FR-4 dielectric substrate. The dielectric constant is 4.4, substrate height is 1.6 mm. The antenna designed on a substrate of dimension 59 mm × 79 mm. Values of different parameters which we used in antenna design are shown below in **Table 1**.

The shape of rectangular patch antenna is shown below in **Figure 2**.

Rectangular Microstrip patch has been designed with $\varepsilon_r = 4.4$ and $h = 1.6$ mm. We designed the rectangular patch for 2.4 GHz, with dielectric substrate of

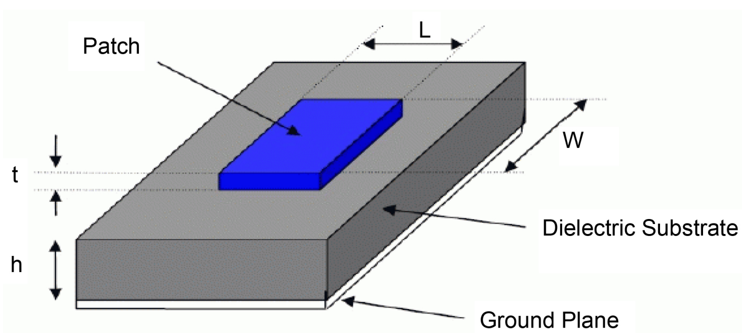

Figure 1. Structure of a microstrip patch antenna.

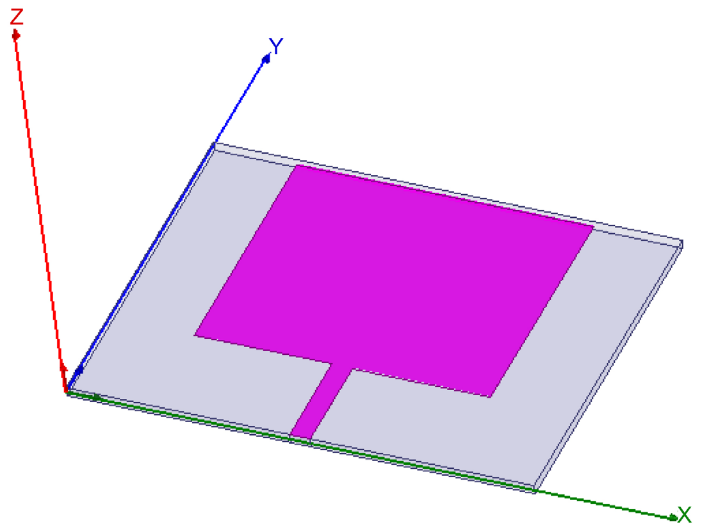

Figure 2. Rectangular microstrip patch antenna.

Table 1. Antenna parameters.

Parameters	Numerical Values
Substrate length	79 mm
Substrate width	59 mm
Substrate height	1.6 mm
Patch length	50 mm
Patch width	41 mm
Feeding length	17 mm
Feeding width	3.5 mm
Slot width	1 mm

thickness "*h*" and relative dielectric constant ε_r. The width and length of the patch can be calculated by

$$W = \frac{c}{2f\left[\left(\varepsilon_r + 1\right)/2\right]^{-1/2}} \tag{1}$$

and

$$L = \frac{c}{2f\sqrt{\varepsilon_e}} - 2\Delta I \tag{2}$$

The antenna was designed using HFSS.

3. Slots in the Ground Plane of Rectangular Patch

We designed microstrip patch antenna with multiple number of slots. We added up to 15 slots in the ground plane with 3 mm spacing. The width of each slot is 1mm. We inserted slots in parallel and horizontally to the feeding line. Each slot line is 2 mm shorter than the previous one. The design for the parallel slots is shown below in Figure 3.

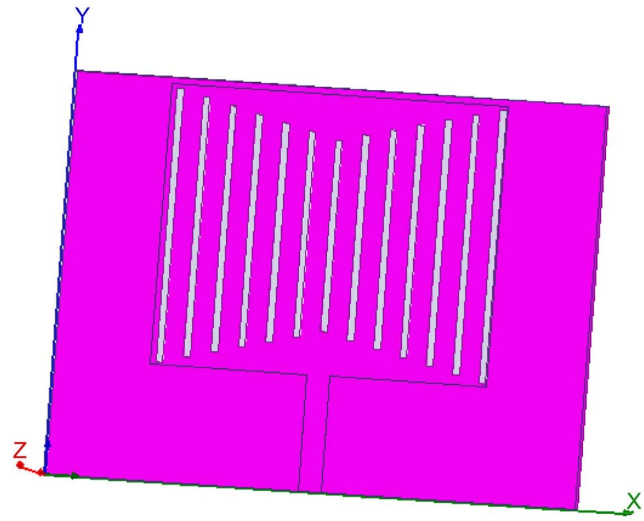

Figure 3. Microstrip patch antenna with slots in ground plane.

The formulas we used to calculate the length and width of patch are shown below.

$$\varepsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\sqrt{1 + 12(h/w)} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.33)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (4)$$

4. Simulation and Results

The proposed antenna was simulated by using HFSS (High Frequency Structure Simulator) as shown in Figure 4.

The simulated reflection coefficient of this antenna is shown below in Figure 5.

The resonance frequency is 2.80 GHz.

The gain of this antenna is shown below in Figure 6.

The antenna gain is 1.0917 dB.

Radiation Pattern of this antenna is shown below in Figure 7. It is an omnidirectional one.

But we still have small region of no coverage in the direction of 0 and −180 degrees.

In this simulation I used: slot width 1 mm, spacing between slots 3 mm, 4 mm distance between the first slot and the edge of the patch and 4 mm distance between the last slot and the other edge of the patch.

Vetically inserted slots are shown below in Figure 8. We inserted 13 slots.

The simulated reflection coefficient for this design is shown below in Figure 9.

We have three resonance frequencies 1.5 GHz, 2.84 GHz and 3.43 GHz which

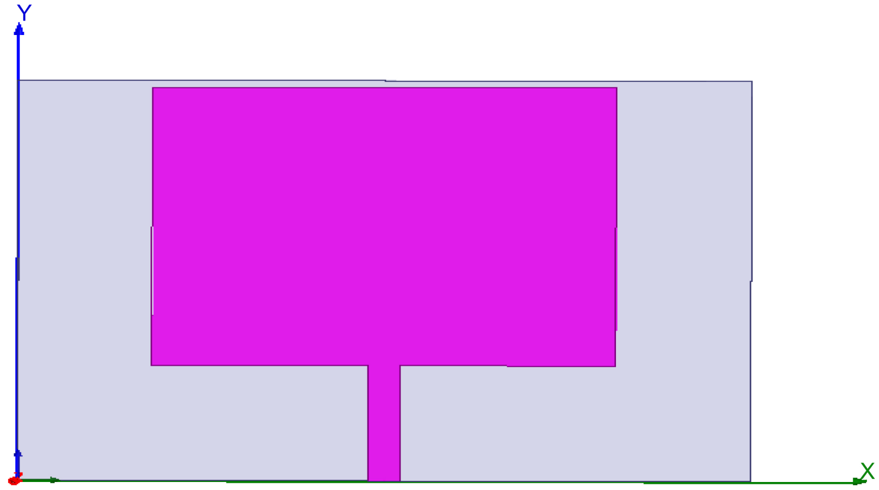

Figure 4. Microstrip patch antenna design.

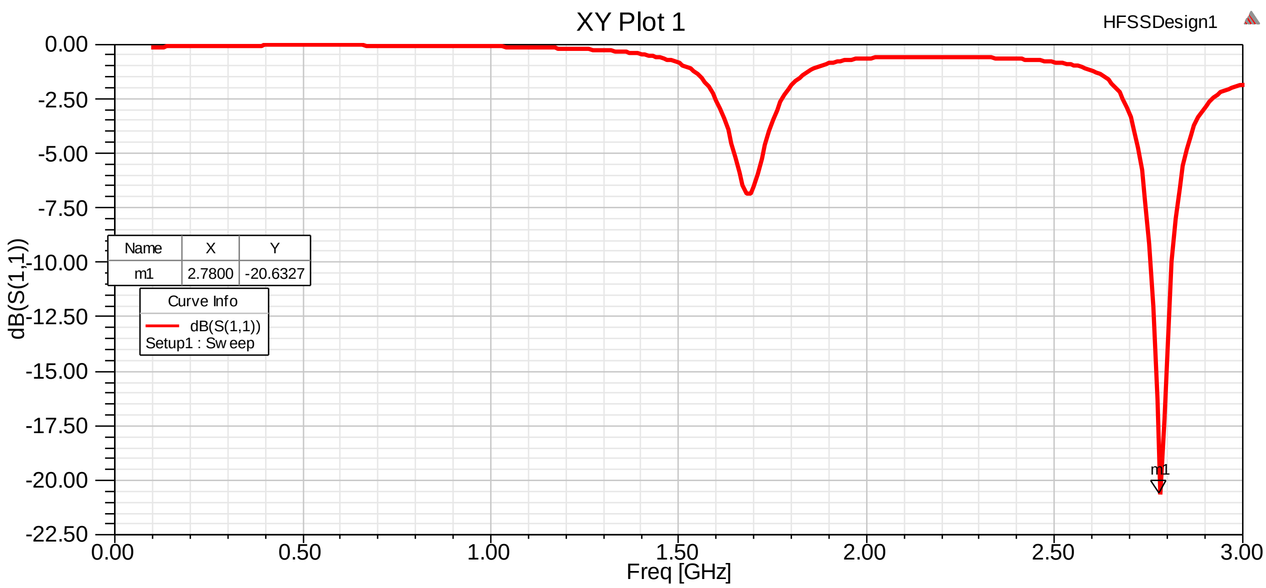

Figure 5. Simulated reflection coefficient of the MPA.

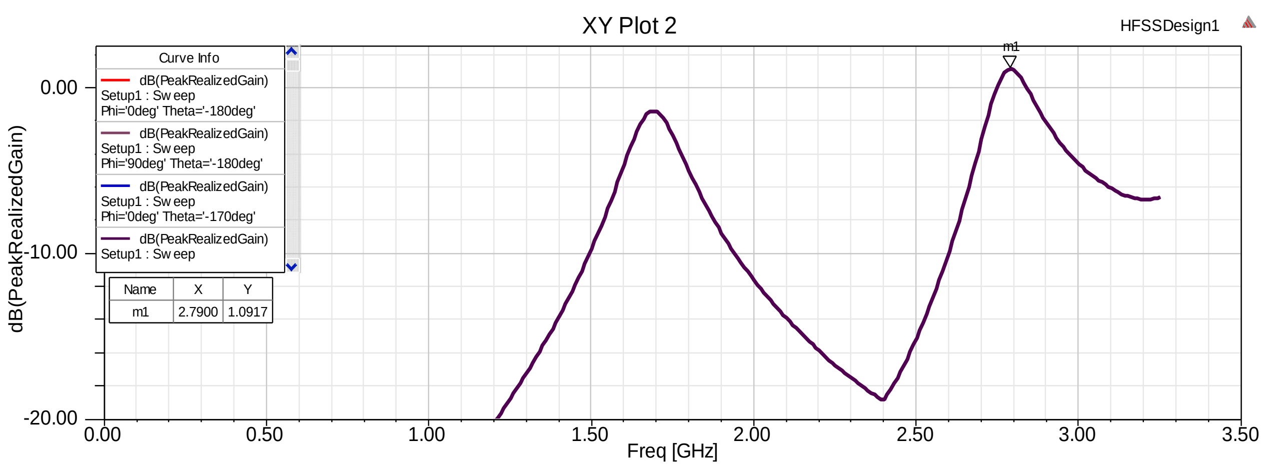

Figure 6. The gain of rectangular MPA.

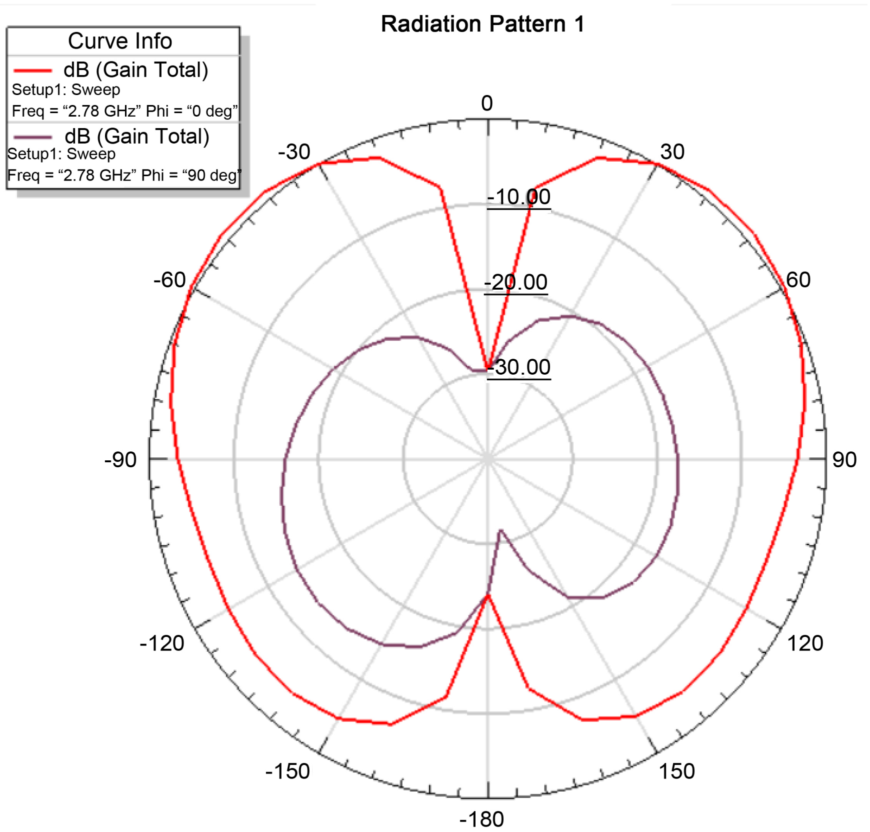

Figure 7. Radiation pattern of rectangular MPA.

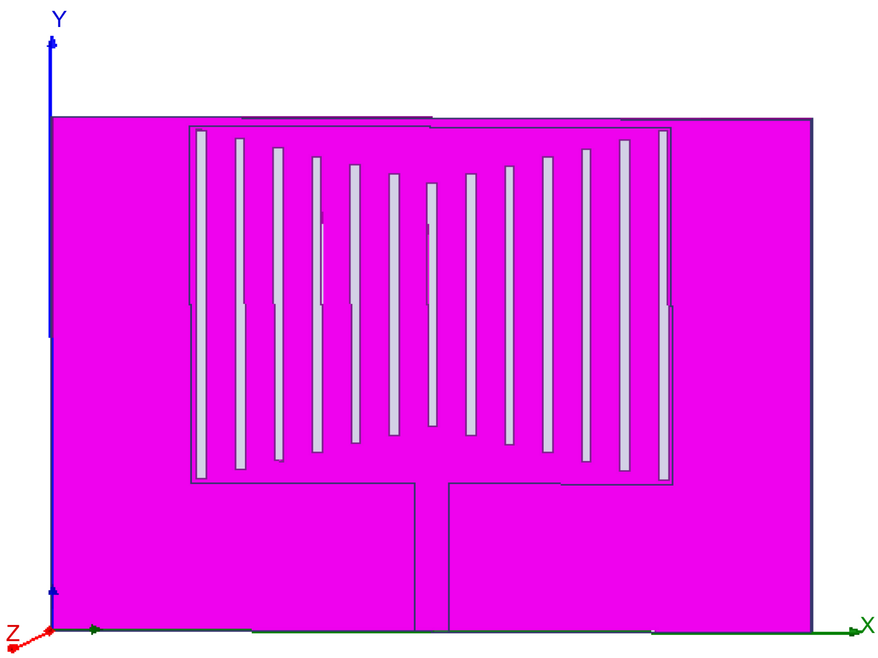

Figure 8. Vertically inserted slots in the ground plane.

makes this design suitable for cognitive radio applications.

The gain of this antenna is shown below in Figure 10.

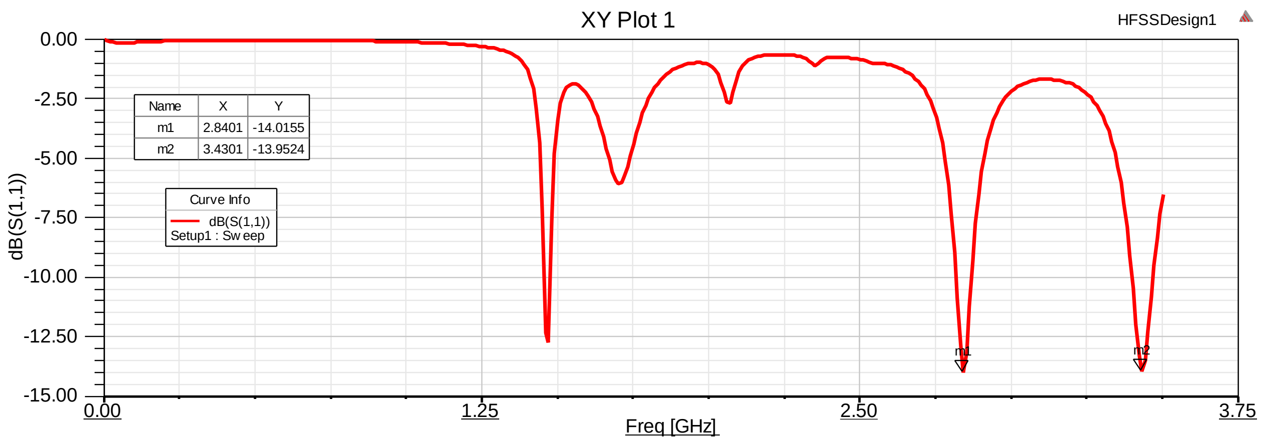

Figure 9. Simulated reflection coefficient for the vertically inserted slots.

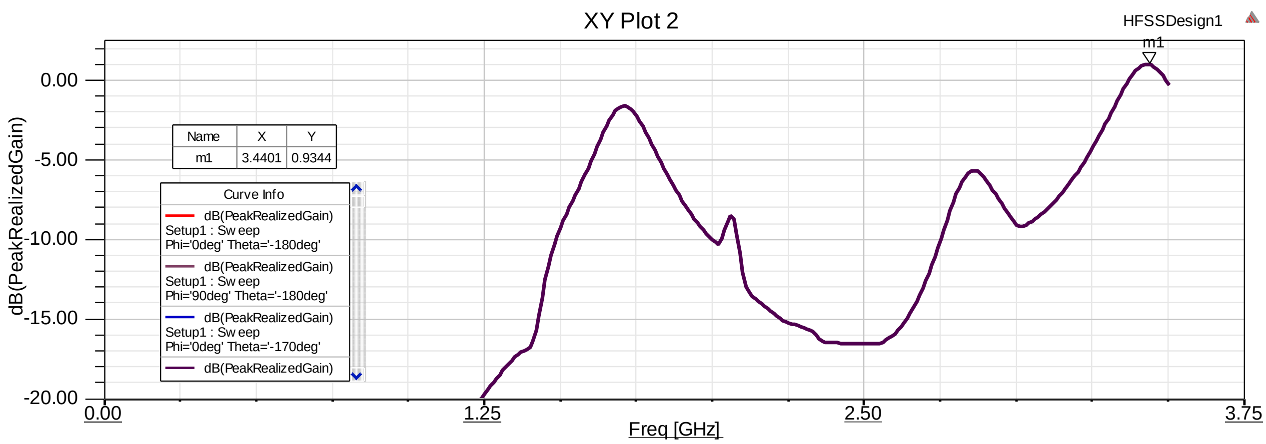

Figure 10. Antenna gain of the vertically inserted slots.

The gain of this antenna is 0.9344 dB.

Radiation pattern of this antenna is shown below in Figure 11.

We observed omnidirectional antenna with better coverage comparing with traditional one.

The horizontally inserted slots are shown below in Figure 12. We inserted 9 slots.

The simulated reflection coefficient for this design is shown below in Figure 13.

In this case we have single resonance frequency at 2.80 GHz.

The gain of this designed antenna is shown below in Figure 14.

The gain of this antenna is 1.1889 dB.

The radiation pattern of this design is shown below in Figure 15.

The results of simulation for horizontally inserted slots are the same as that for microstrip patch antenna without slots.

Results of simulation for Return loss characteristics of the designed MPA is shown below in Figure 16.

We compared the results of simulation for the antenna with vertically inserted slots to the results of simulation for the case without slots.

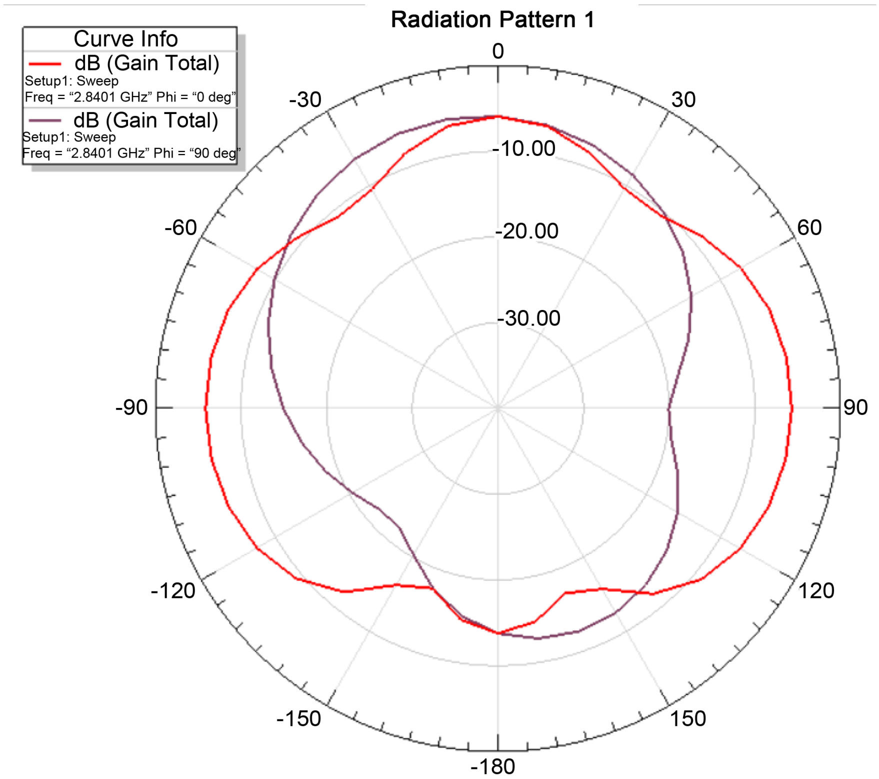

Figure 11. Radiation pattern of this antenna.

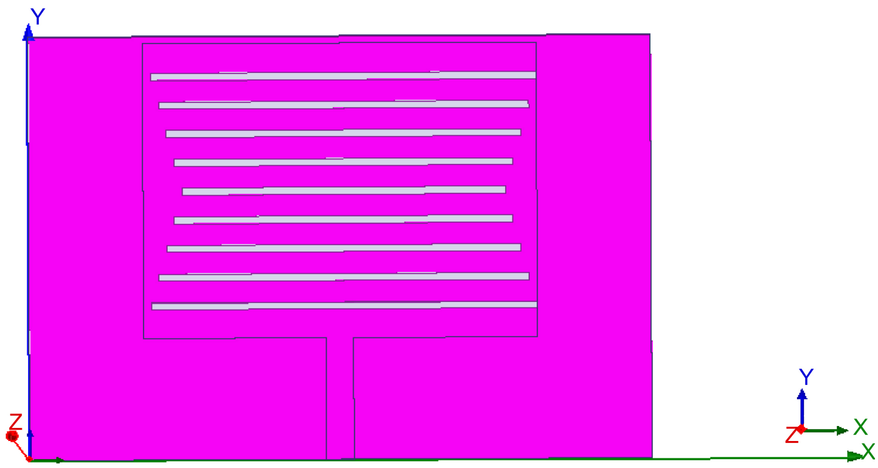

Figure 12. Horizontally inserted slots.

We can see that the conventional patch antenna without slots exhibit only one resonant frequency at 2.8 GHz, whereas with vertically inserted slots in the ground plane the patch antenna exhibits multiple number of resonant frequency with one wide band frequency response, at 1.4 GHz and 1.80 GHz. Wide band response is observed from 2.43 GHz to 2.97 GHz approximately. It can also be shown from the above figure that the −10 dB bandwidth is also increased with slots. The bandwidth of patch antenna without slot is 47 MHz, whereas the bandwidth of patch antenna with slots is approximately 540 MHz. This shows

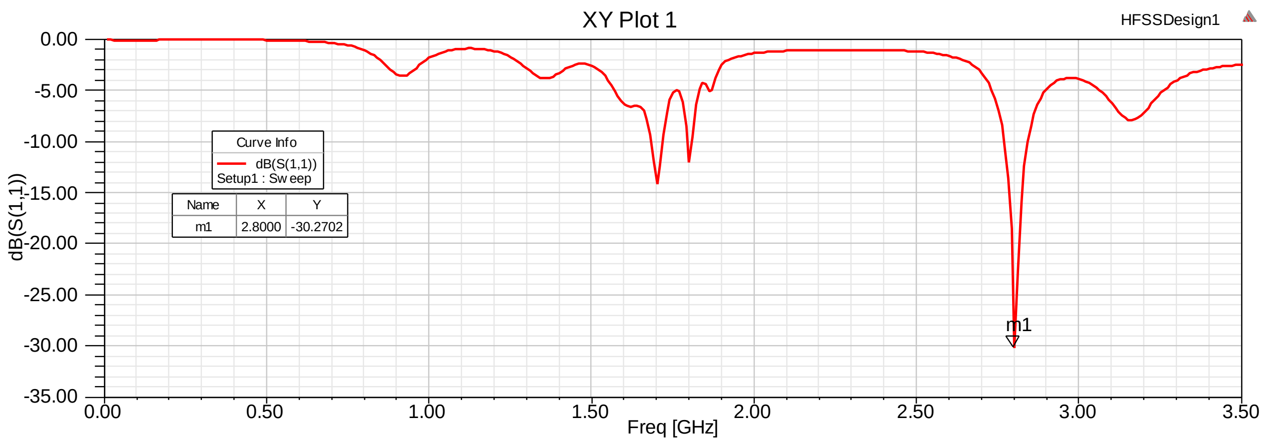

Figure 13. Simulated reflection coefficient for the horizontally inserted slots.

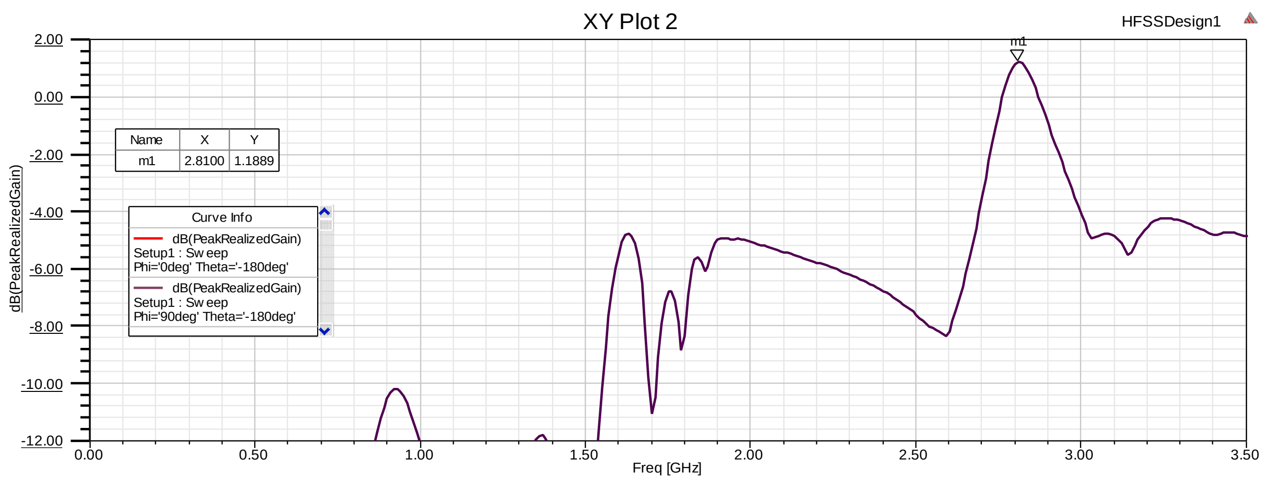

Figure 14. The gain the horizontally insrted slot.

that the bandwidth of patch antenna with slots is enhanced approximately 493 MHz with respect to conventional antenna. From the above figures it can be shown that the gain of patch and directivity with slots is approximately the same as conventional patch antenna. The gain of patch antenna with and without slots is 1.899 dB and 2.185 dB respectively. The directivity of the patch antenna with and without slots is 5.353 dBi and 6.159 dBi respectively.

5. Conclusion

In this work, the bandwidth of the microstrip patch antenna has been enhanced using multiple numbers of slots in the ground plane. The multiple bands and a wide band response are achieved by using this technique. From Figure 16, we can see that the simulated results showed very much improvement in the antenna bandwidth while keeping antenna gain and directivity without considerable changing. The antenna shows bandwidth up to 540 MHz compared to the conventional one which was only 47 MHz. We obtained 18% bandwidth improvement. Also inserting vertical slots in ground plane provided omnidirectional antenna pattern with better coverage. This antenna can be used in cognitive radio

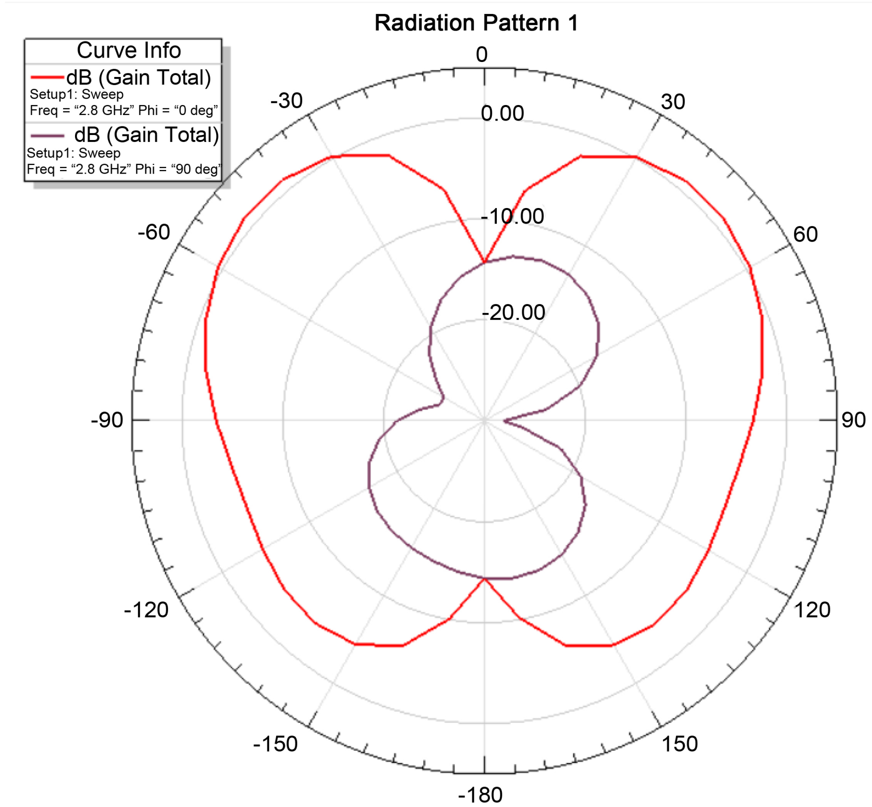

Figure 15. Antenna radiation pattern of the horizontally inserted slots.

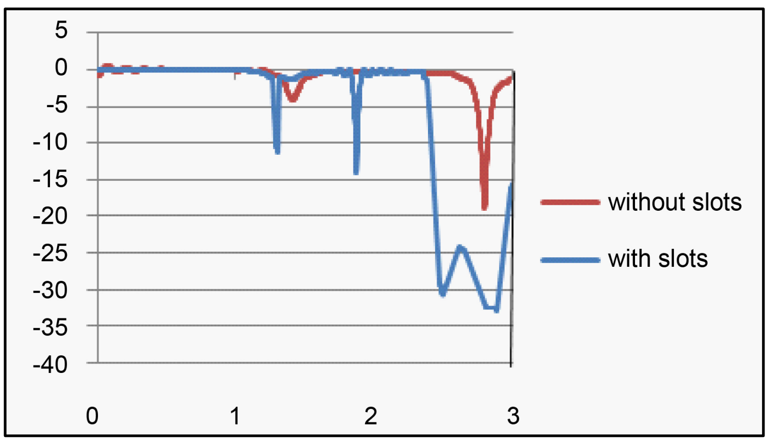

Figure 16. Comparison of simulated return loss characteristics of patch antenna with and without slots.

applications. It can be concluded that the proposed design has been successfully implemented for rectangular patch antenna and also can be used for other types of patch antennas as well.

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Claim

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