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Bandwidth Enhancement of Microstrip Patch Antenna

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Abstract

Microstrip patch antenna (MPA) is suitable for different applications in wireless communications. MPA suffers from low gain and narrow bandwidth. In this paper we improved its bandwidth by inserting multiple slots in its ground plane. We used FR-4 substrate to design this antenna. The dimensions of this antenna are 60mm and 80mm. The dielectric constant is equal to 4.4 and the height is 1.6mm. We inserted up to 12 slots in ground plane with 1mm width. The spacing between slots is 3mm slots were arranged parallel to the feeding line. Simulation was done using HFSS simulator.

Keywords: Microstrip Patch Antenna, Bandwidth, Gain, Ground Slots and HFSS Simulator

1. Introduction

Communication systems deals with transmitting information bearing signals through channel from transmitter to the receiver. The antenna is used in both transmitting and receiving parts of communication system to convert voltage or current into electromagnetic signals during transmission and vice versa during reception. MPA are commonly used in different Communication systems because of their small size, high gain and their wide coverage pattern. One of their disadvantages which limits there widely implementation is narrow bandwidth. MPA are used in different applications like wireless communication including mobile systems. They are also used in computer links, remote controls and satellite communication systems. MPA usually consists of a radiating patch which is made of conducting material such as gold or copper. It can take any possible shape rectangular, triangular, square, or circle (Khraisat, Olaimat, & Abdel-Razeq, 2012). The radiating patch and the feed lines are usually inserted on the dielectric substrate as shown in Figure 1.

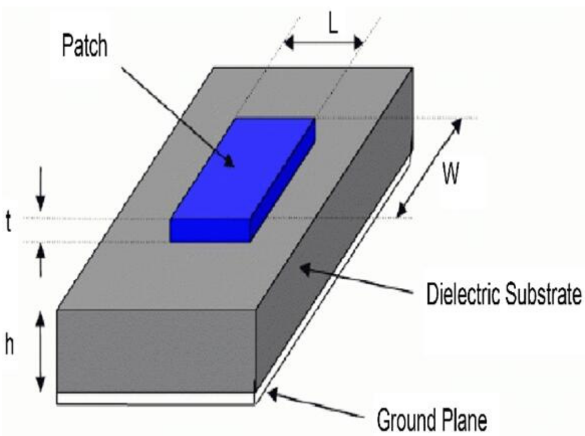

Figure 1. Structure of a microstrip patch antenna

In (Thakare & Singhal, 2009), authors inserted slots into MPA to improve its bandwidth. They demonstrated the design of slotted microstrip antenna on a substrate of thickness 1.588mm that gives wideband characteristics. The illustrated patch antenna provides bandwidth enhancement compared to antenna without slots of the same physical dimensions. The simulation was obtained by using IE3D simulator.

In (Roy, Môm, & Igwue, 2013), three different geometry shapes, the U, E and H were developed from a rectangular patch of width (W) = 32mm and length (L) = 24mm. Bandwidth improvement by 4.81% for 100MHZ, 28.89% for 610MHz, 9.13% for 630MHz and 9.13% for 110MHz.

In (Abu Tarboush, Al-Raweshidy, & Nilavalon, 2009), authors improved antenna bandwidth by 25% which was obtained by inserting slots on ground plane and stacked patch supported by wall. This design doesn't affect the frequency of operation. In (Liu, Cheung, & Yuk, 2011), Slots of different shapes triangular or rectangular were placed on the ground plane under the feed line of the radiator for bandwidth improvement and impedance matching.

2. Antenna Design Procedure

We investigated rectangular MPA with and without slots on FR-4 dielectric substrate. The dielectric constant was 4.4, substrate height was 1.6mm. The antenna developed on a substrate of dimension 60mm x 80mm. Values of different parameters which we used in antenna design are shown in Table 1.

Table 1. Antenna Parameters

Parameters	Numerical Values
Substrate length	80mm
Substrate width	60mm
Substrate height	1.6mm
Patch length	50mm
Patch width	41mm
Feeding length	17mm
Feeding width	3.5mm
Slot width	1mm

The shape of rectangular MPA with inset feed is shown in Figure 2.

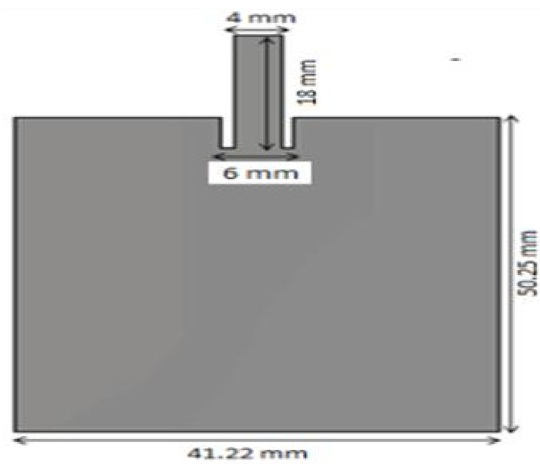

Figure 2. Rectangular Patch Antenna

Rectangular Microstrip patch was designed with εr = 4.4 and h = 1.6mm. The patch was designed for 2.4GHz, with dielectric substrate of thickness 'h', and relative dielectric constant εr. The width and length of the patch can be calculated by

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

and

$$L = \frac{c}{2f\sqrt{\varepsilon_e}} - 2\Delta l \quad (2)$$

The antenna was designed using HFSS.

3. Slot in the Ground Plane of Rectangular Patch

They are different methods by which slots are inserted into MPA. In (Liu, Cheung, & Yuk, 2011), three slots in the ground plane were designed as shown in Figure 3. The three slots were made along the axis of resonating length. Two slots were inserted in one side of the patch and third one was inserted in other side. This antenna was investigated by changing slots length and width in the ground plane. The antenna has a rectangular radiating patch of dimensions L x W. Three identical slots were inserted in the antennas ground plane and aligned with an equal spacing of L/4 and in parallel with the patches radiating edges or the y-axis. In this design the slot width was 2mm. The microstrip patchwas fed coaxially at distance L/4 from the center of the non-radiating edge for good impedance matching purposes.

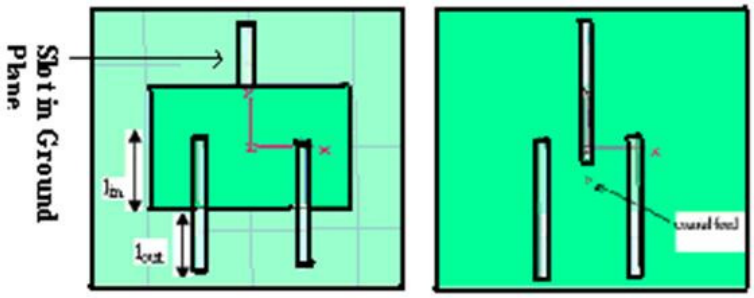

Figure 3. Microstrip Rectangular Patch

Nearly square microstrip Patch was developed on a FR4 substrate with εr = 4.3 and h = 1.6mm with aspect ratio = 0.985. The microstrip patch was fed coaxially at position (-4.5, -5.5)mm along the diagonal as shown in Figure 4. The 4 slots were etched in patch. The effect of slots were studied by changing the length and the width of the slot. This design taked into account the measurements of impedance, bandwidth, half power beam width, gain and efficiency.

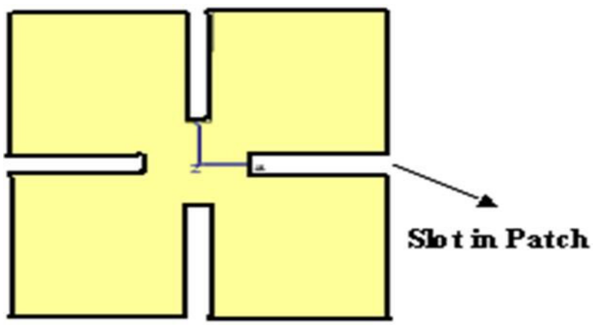

Figure 4. Square Microstrip Patch with Four Slots

We investigated MPA with multiple number of slots. We added 12 slots in the ground plane with 3mm spacing. The width of each slot was 1mm. All slots were arranged in parallel to the feeding line. Each slot line is 2mm shorter than previous one. The design is shown in Figure 5.

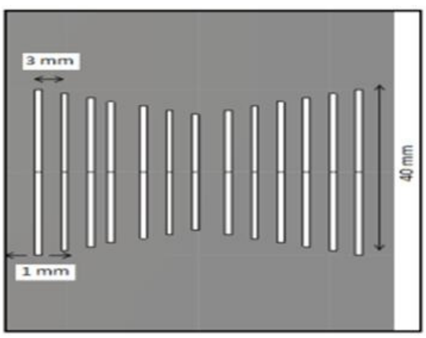

Figure 5. Microstrip patch antenna slots in ground plane

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

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

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

4. Simulation and Results

The proposed antenna was simulated by HFSS (High Frequency Structure Simulator) as shown in Figures 6 and 7.

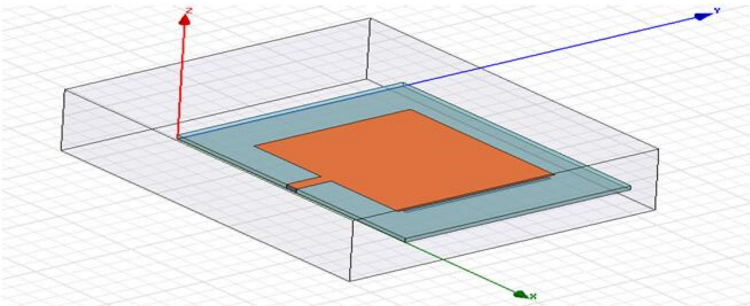

Figure 6. Microstrip patch antenna design

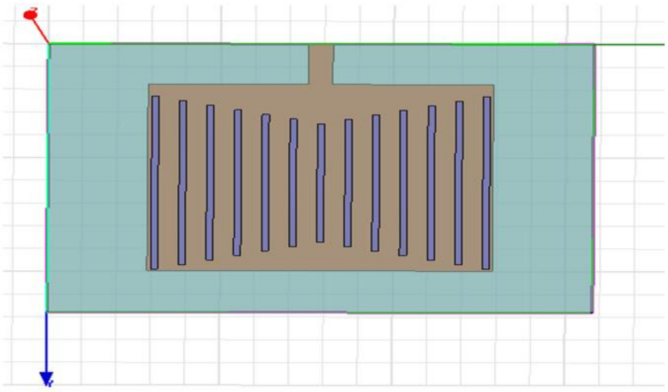

Figure 7. Design of slots in the ground plane

Return loss characteristics Results of the designed MPA is shown below in Figure 8.

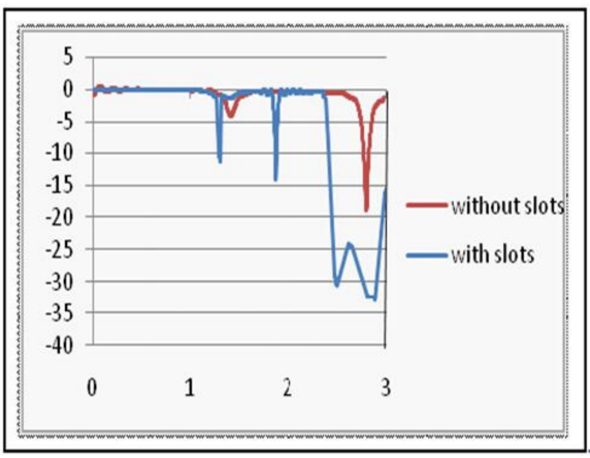

Figure 8. Comparison of return loss characteristics of the patch antenna with and without slots

Comparison was made for the case of inserting slots with the case of no slots as shown in Figure 8.

We noticed that the conventional patch antenna without slot exhibit only one resonant frequency at 2.75GHz, whereas antenna with slots exhibits multiple number of resonant frequencies: at 1.35GHz and 1.75GHz. Wide band response was obtained from 2.43GHz to 2.97GHz.

The bandwidth of patch antenna without slot was 47MHz, whereas the bandwidth of the same antenna with slot was 540MHz. The bandwidth of patch antenna with slot was enhanced approximately 493MHz with respect to conventional antenna.

The variation of far field properties of patch antenna with and without slots are shown in Figures 9 and 10.

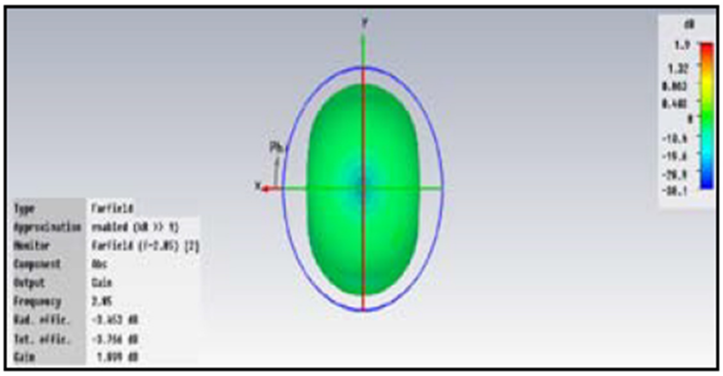

Figure 9. Far field pattern of patch antenna with slot

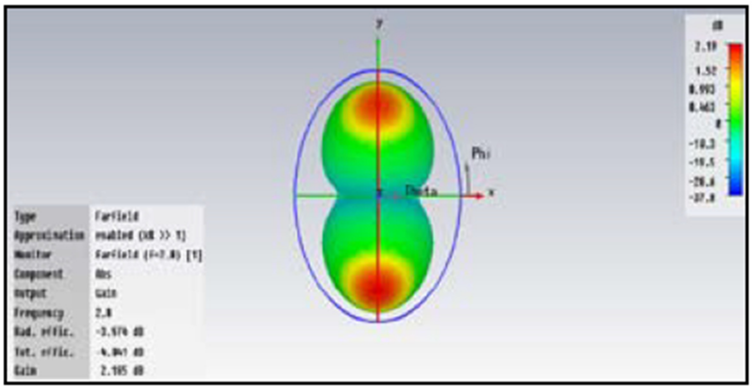

Figure 10. Far field pattern of conventional patch antenna

From the above Figures it can be seen that the gain and directivity with and without slots were not affected. The gain of patch antenna with and without slots is 1.899dB and 2.185dB respectively. The directivity of the patch antenna with and without slots is 5.353dBi and 6.159dBi respectively.

5. Conclusion

The bandwidth of the MPA has been improved using multiple numbers of slots in the ground plane. The multiple bands and a wide band response are achieved by using this technique.

The antenna with slots shows bandwidth up to 540MHz compared to the conventional one which was only 47MHz. However, it can be concluded that the proposed design can be also implemented for other shapes of patch antennas.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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