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Wide-Band Comb-Shaped Slotted Microstrip Patch Antenna

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Abstract: This paper presents a novel wideband microstrip patch antenna: comb-shaped microstrip patch antenna. It is designed to work on a foam substrate that has a thickness of 15 mm and a relative permittivity (ε_r) of near one. Two pair parallel slots are incorporated into the microstrip patch antenna in order to increase its bandwidth. An input impedance bandwidth of 29% for VSWR≤2 has been obtained from the proposed antenna. Effects of varying the parameters of comb-shaped slot on the performance of antenna have also been studied. The radiation pattern and directivity are also presented.

Index Terms: Slot cut, Comb-shaped, Two pair slots, Wide-band antenna, Patch antenna.

I. INTRODUCTION

Microstrip patch antennas are currently being used for many applications due to several key advantages such as the low cost, low profile, light weight and ease of fabrication. However, microstrip antennas inherently have a narrow bandwidth. To overcome this limitation, many techniques have been suggested. The conventional method to increase the impedance bandwidth is using parasitic patches. Increasing the height of the substrate is other method to extend the bandwidth [1]. However, as the height increases, surface waves are introduced which usually are not desirable because they extract power from the total available power for direct radiation. Stacking of microstrip elements, as well as other methods, can also be used to increase the bandwidth [1]-[3]. However, these methods typically enlarge the antenna size, either in the antenna plane or antenna height. In [4], the authors presented an E-shaped patch antenna, which two parallel slots are incorporated into the antenna patch to increase the antenna bandwidth and demonstrated that its bandwidth could exceed above 30%.

In this paper, a novel probe fed slotted wideband microstrip patch antenna is presented. For this antenna, the impedance bandwidth, determined from a 10-dB return loss, is about 565MHz or 29% with respect to the center frequency at 1942.5 MHz, which is the average of the measured lower and higher frequencies with a 10-dB return loss. This bandwidth is achieved by using "two pair of slots" into the patch of the microstrip antenna. Radiation pattern and directivity are also presented. The simulation of antenna structure was performed with Ansoft HFSS software [5].

This paper is organized as follow. Section II presents the configuration of the proposed antenna. Parametric study of antenna is investigated in section III. The results are discussed in section IV. Subsequently, section V concludes the paper.

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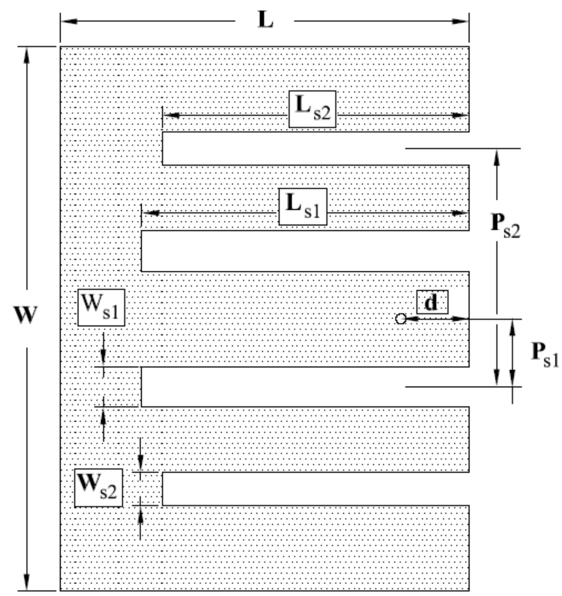

Figure 1. Geometrical configuration of the proposed comb-shaped antenna.

II. ANTENNA CONFIGURATION

The geometry of the proposed antenna with its parameters is depicted in Figure 1. The antenna has only one patch. The patch size is determined by (L, W) and it is fed by a coaxial probe at position d. The proposed antenna is printed on a foam with relative permittivity (εr) of near one, thickness of 15 mm, and ground plane size of $L_g \times W_g$ = 150 mm × 150 mm. In order to increase the antenna bandwidth, four parallel slots are incorporated into this patch. These slots are positioned symmetrically in relation to the feed point and resembles comb-shape patch. The parameters of slots are:

- Slot Lengths (L_{s1}, L_{s2})
- Slot widths (W_{s1}, W_{s2})
- Position of the slots (P_{s1}, P_{s2})

These parameters are very important to matching antenna to a 50Ω coaxial line and therefore in controlling the achievable bandwidth.

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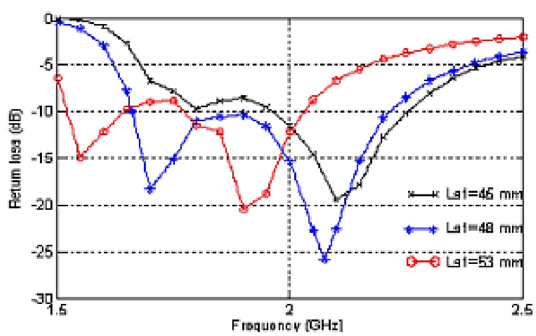
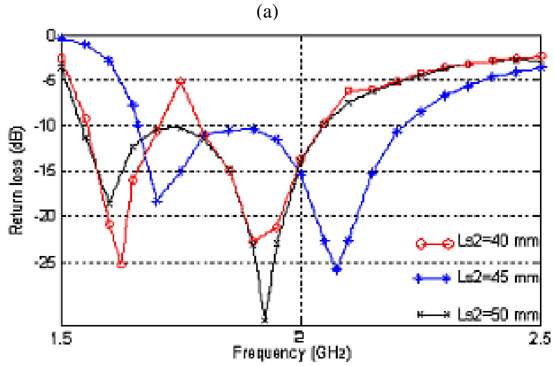
Generally the microstrip patch antenna has been modeled as a simple LC resonant circuit [6]. Values of resonant elements are determined by currents path lengths. When slots are cut on the patch, the flow paths of the electrical currents are also cut. The current has to flow around the slots and the equivalent length of the current flow path gets longer. Thus, the resonant frequency will decrease. This effect can be modeled as an additional series inductance [7]. Therefore, the antenna changes from a single resonance frequency circuit to a dual resonant circuit. These two resonant circuits couple together and form a wide bandwidth.

The high resonance frequency is mainly characterized by the basic patch width W, and the low resonance frequency is mainly determined by the slots [4], as we have mentioned above.



(a)



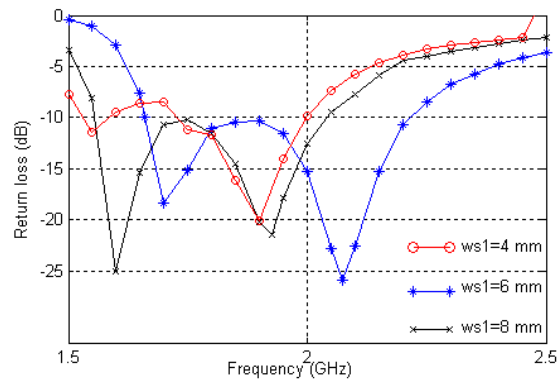
(b)

Figure 2. Calculated S_{11} of Comb-shaped antenna with different slot lengths. (a) Effect of inner slot lengths. (b) Effect of outer slot lengths.

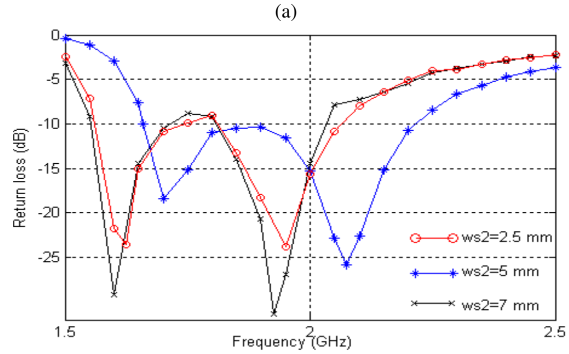
III. Parametric Study of Antenna

The slots are important in controlling the wide-band behavior of the comb-shape patch antenna. In order to achieve the desired wide-band characteristics, the effects of the parameters of parallel slots on the antenna behavior are studied.

Figure 2 shows the effect of the slots lengths on the performance of the antenna. When the length of inner slots (Ls1) is small, the antenna has only one resonance frequency. By increasing this length in additional of the



(a)



(b)

Figure 3. Calculated S_{11} of Comb-shaped antenna with different slot width. (a) Effect of inner slot width. (b) Effect of outer slot width.

original resonance frequency, another lower resonance frequency appears. If this length becomes larger the secondary resonance frequency even becomes smaller, as shown in figure 2(a). The effect of the length of outer slots can also be observed from Figure 2(b). To sum up, the length of slots are important parameters in determining the resonant frequencies.

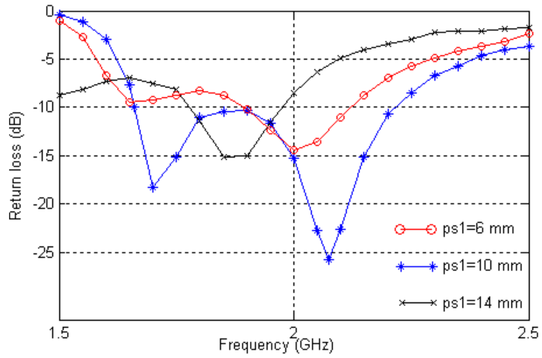
The effect of the width of the slots is discussed in Figure 3. From this figure it can be seen that the slot's width playing important role in achieving wide bandwidth. The best impedance matching can be obtained when the width of the inner and outer slots are equal to 6mm and 5mm, respectively.

Figure 4 illustrates the effect of various positions of slots on antenna. When the ps1 is small, the return loss is greater than -10 dB at low resonance frequency. As ps1 becomes larger, the wider bandwidth is obtained. However, when this parameter becomes even larger degrades the matching between antenna and 50Ω.

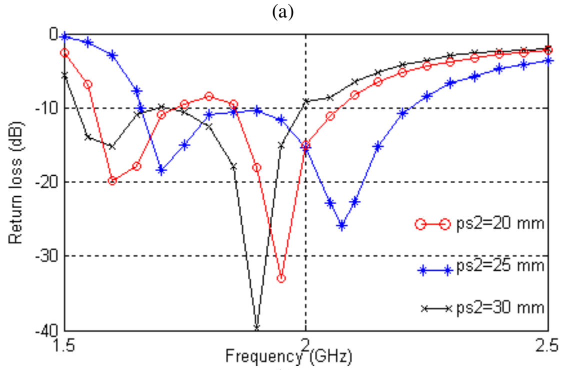
IV. Results and Discussions

A. SWR

The curve of VSWR for proposed UWB antenna with dimensions presented in TABLE I is depicted in Figure 5. As shown in this figure from simulation result by HFSS, we can see that the bandwidth of the proposed antenna is 1.66 GHz to over 2.22 GHz for VSWR ≤ 2.



(a)



(b)

Figure 4. Calculated S_{11} of Comb-shaped antenna with different slot positions. (a) Effect of inner slot position.
(b) Effect of outer slot position.

TABLE I
DIMENSIONS OF THE PROPOSED COMB-SHAPED ANTENNA.

Parameter	W	L	L_{s1}	L_{s2}	W_{s1}	W_{s2}
Value (mm)	80	60	48	45	6	5

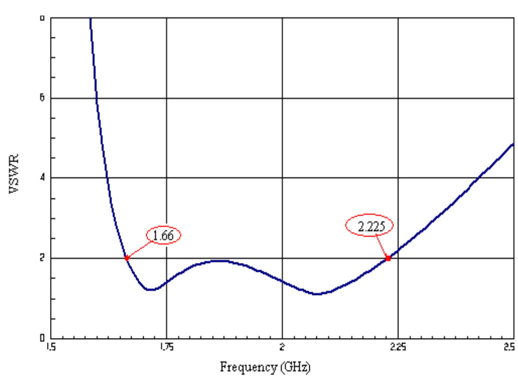


Figure 5. The curve of VSWR for proposed wide-band antenna with dimensions presented in TABLE I.

B. Radiation Pattern and Directivity

The directivity of proposed antenna for frequency range of within 1.5-2.5GHz is shown in Figure 6. The values of directivity at resonance frequencies of 1.7 GHz and 2.075 GHz are observed to be 8.72 and 9.32 dB respectively.
The radiation characteristics of the antenna have also studied. Figure 7 represents the radiation patterns of the proposed antenna for tree different operating frequencies. As it is obvious from the figure, the proposed antenna has almost similar radiation pattern at thesetree frequencies.

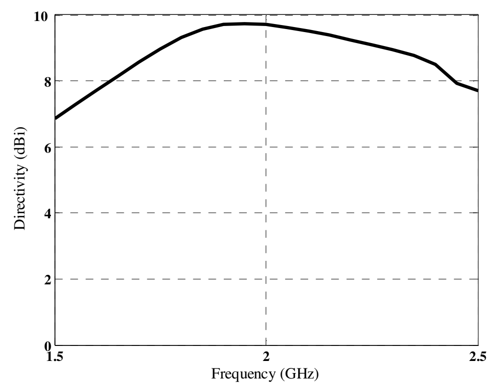


Figure 6. The calculated directivity of the proposed comb-shaped antenna.

IV. COCLUSION

A novel comb-shaped microstrip antenna for wideband communication is presented in this paper. In order to achieve wide-band characteristic, two pair parallel slots is utilized in to the rectangular microstrip patch. By adjusting the parameters of the parallel slots the antenna performance can be controlled. Numerical study of the effect of the principal parameters of the parallel slots on the antenna performance is carried out. The proposed antenna has frequency bandwidth of 29% for VSWR≤2 with respect to the center frequency.

Acknowledgment

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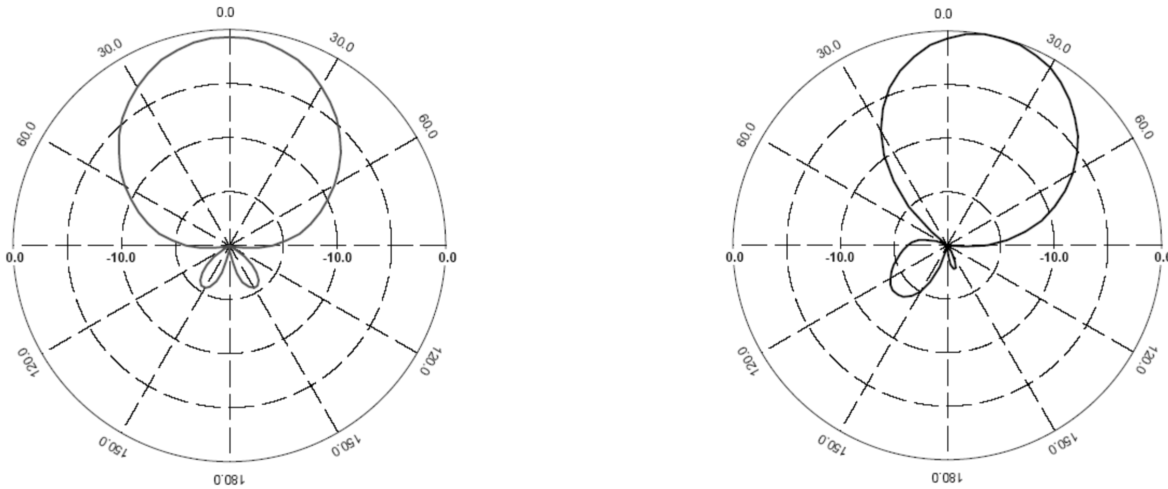
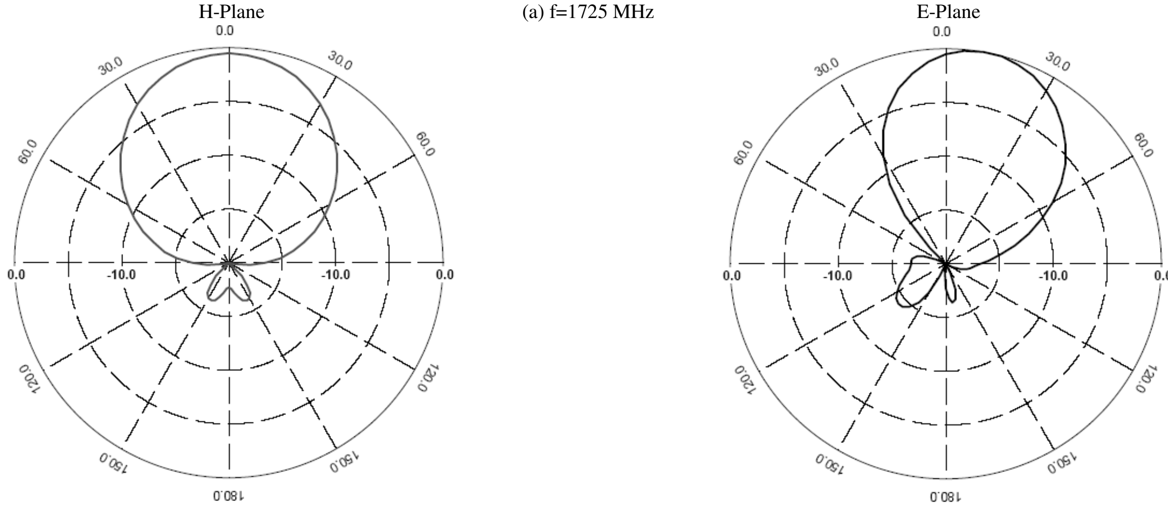
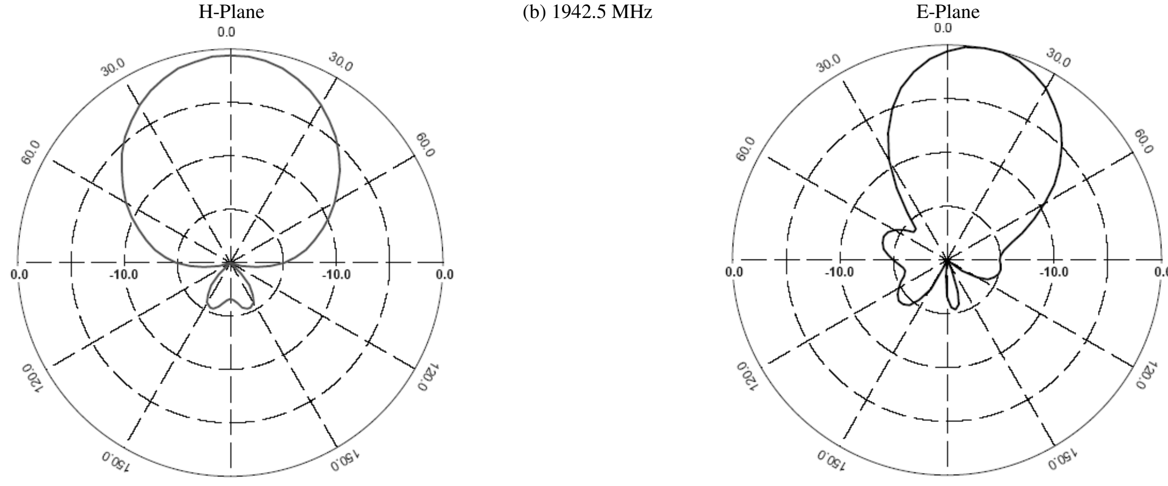


H-Plane (a) f=1725 MHz E-Plane



H-Plane (b) 1942.5 MHz E-Plane



H-Plane (c) 2075 MHz E-Plane

Figure 7. The E-plane and H-plane radiation patterns of proposed comb-shaped antenna.

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