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MULTI-WIDEBAND COMPACT MICROSTRIP PATCH ANTENNA BASED ON SLOT MATCHING

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Abstract—This paper presents a new design of a compact patch antenna based on the slot matching concept. Switches are integrated with the previously inserted slots into the patch antenna to enhance the performance. The newly designed antenna is a multi-wideband antenna. It is able to achieve a return loss less than −9.54 dB and VSWR≤2 in more than four frequency bands in the range from 2 to 5 GHz.

1. INTRODUCTION

Conventional microstrip patch antennas, in general, have a conducting patch printed on a grounded microwave substrate. They have attractive features of low profile, light weight and easy fabrication. However they inherently have a narrow bandwidth [1–3]. Moreover the impedance bandwidth of a patch antenna is proportional to the antenna dimensions measured in wavelengths. Therefore the size reduction and bandwidth enhancement are becoming major design consideration and usually demanded for practical applications [4].

Present-days mobile communication systems usually require a small antenna size in order to meet the miniaturization requirements of mobile units [5]. Many designs and techniques such as meandered slots in the ground plane [6], slot-loaded [7, 8], stacked shorted patch [9], E-shaped with compatible feeding [10] and chip resistor loading[11] have been reported to achieve a wideband and reduced size antennas. Moreover the multi-band antennas are important in areas such as mobile communication handsets and base stations systems [12, 13]. Several approaches are developed in order to design multi-band patch antennas such as slot matching concept [13], compact H-shaped configurations [14, 15], slotted ground plane [16], shorted patches [17], and patch antennas with perturbation elements in a grid of conductive cells [18]. All these suggested configurations do not achieve enhancement wide bands operation.

In this paper, a new design of multi-wideband compact microstrip antenna is presented. The aim of the suggested design is to manipulate a microstrip patch antenna of a multi-wideband in the frequency operation range. We combine parasitic elements and slots with switches into the antenna. The simulation of the proposed antenna has been carried out using IE3D Zeland software [19]. Description of the antenna design is outlined in the following sections.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The newly manipulated patch antenna consists of a conventional patch antenna having the following optimal specifications and dimensions as reported in the literatures with little change in the feed location and substrate thickness [20]. The center frequency is 2.4 GHz, the ground plane dimensions are $50.95 \times 59\,\text{mm}^2$, the patch dimensions are $41.35 \times 49.41\,\text{mm}^2$. The dielectric substrate between the patch and the ground plane is of RT/ Duroid 5880 with relative permittivity $\varepsilon_r = 2.2$ and thickness of 1.6 mm. The ε_r is chosen such that it gives better efficiency and larger bandwidth [21]. The antenna is fed by a coaxial probe feed of radius 3 mm. In order to increase the number of resonance frequencies and to enhance the bandwidth and gain of the conventional microstrip antenna a multi-band parasitic resonator elements are inserted into the antenna [13]. To tune the resonant

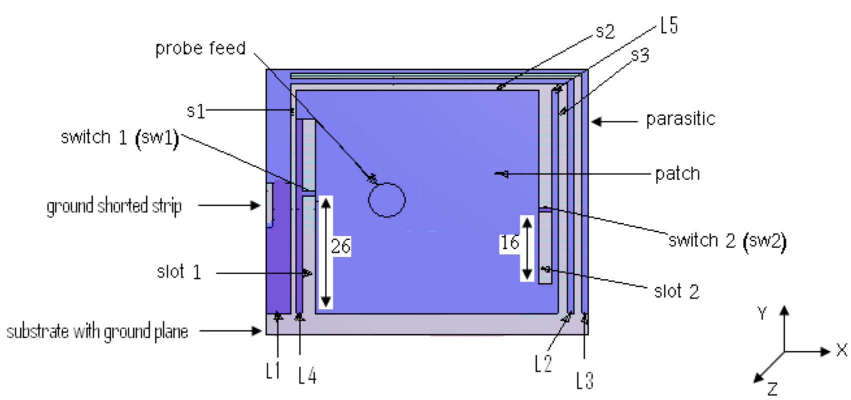


Figure 1. The Geometry and parameters of the proposed antenna.

frequencies of the parasitic resonantors, two slots are added to the patch. Moreover, switches are integrated into the slots where the current paths become shorter and hence the operating frequencies increase [20]. The specifications of the proposed antenna are present in Table 1. The positions and dimensions of the parasitic, slots and switches are optimally chosen to give as many resonant frequencies as possible.

Table 1. Specifications of the proposed antenna.

Elements	Dimensions (mm)
Ground plane	50.95x59(LxW).
Patch	41.35x49.41(LxW).
Patch thickness	0.07
Substrate thickness	1.6
Feed point location	X_{f} = - 6.35, Y_f = 0.0, the center of the antenna is at (0,0).
Probe feed radius	3.
Parasitic	L_1=4 mm, L_2=L_3=1.
Ground shorted strip	1x8(LxW).
The slot between the parasitic arms	1.3
Widths of the slots around the patch	S1=0.8, S2=1.495, S3=1.5
Slots(Slot 1 & Slot 2)	43x2(LxW) at distances L4=L5=1mm from S_1 and S_3.
Switches(SW_1 & SW_2)	1x2(LxW) at 26 mm from the open edge of the slots.

3. SIMULATION AND RESULTS

The proposed antenna is simulated using Zeland software's IE3D simulation package [19]. For an initial design the optimum feed point is found to be at $(X_f, Y_f) = (-6.35, 0)$ at which the return loss (RL) is -52.9339 dB at frequency 2.3975 GHz which is very closed to the desired operating frequency 2.4 GHz. Figure 2 shows the computed results of the RL as a function of frequency for the conventional antenna as well as for the conventional antenna with the parasitic elements. The results illustrated that when the parasitic resonator elements are enclosed to the patch more resonant frequencies are obtained with RL less than -9.54 dB in the range of 2–5 GHz. The number of the resonant frequencies can be increased using two slots with two switches sw_1 and sw_2 inserted into the patch. We optimally choose the positions of these two switches. The resonant frequencies depend on the states of the two switches. The computed results of the RL as a function of frequency are shown in Figs. 3(a) and 3(b) for different stares of sw_1 and sw_2 either on or off. The state at which sw_1 and sw_2 are simultaneously on represents the optimal case of the

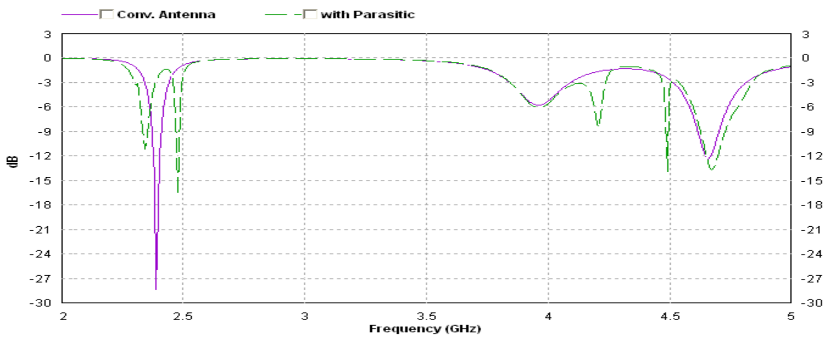
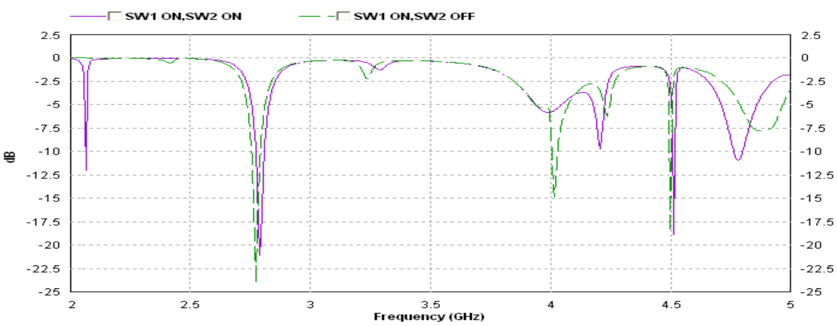
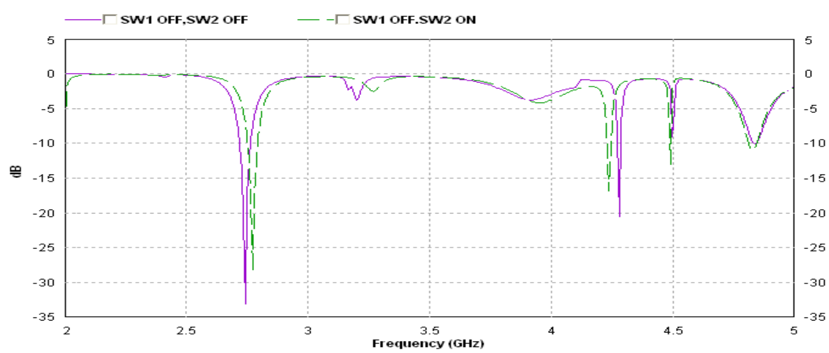


Figure 2. Return loss as a function of frequency for the conventional antenna and the conventional antenna with the parasitic.



(a)



(b)

Figure 3. Return loss as a function of frequency for the proposed antenna: (a) the state of sw_1 and sw_2 are on, and the state of sw_1 is on and sw_2 is off, (b) the state of sw_1 is off and sw_2 is off, and the state of sw_1 is off and sw_2 is on.

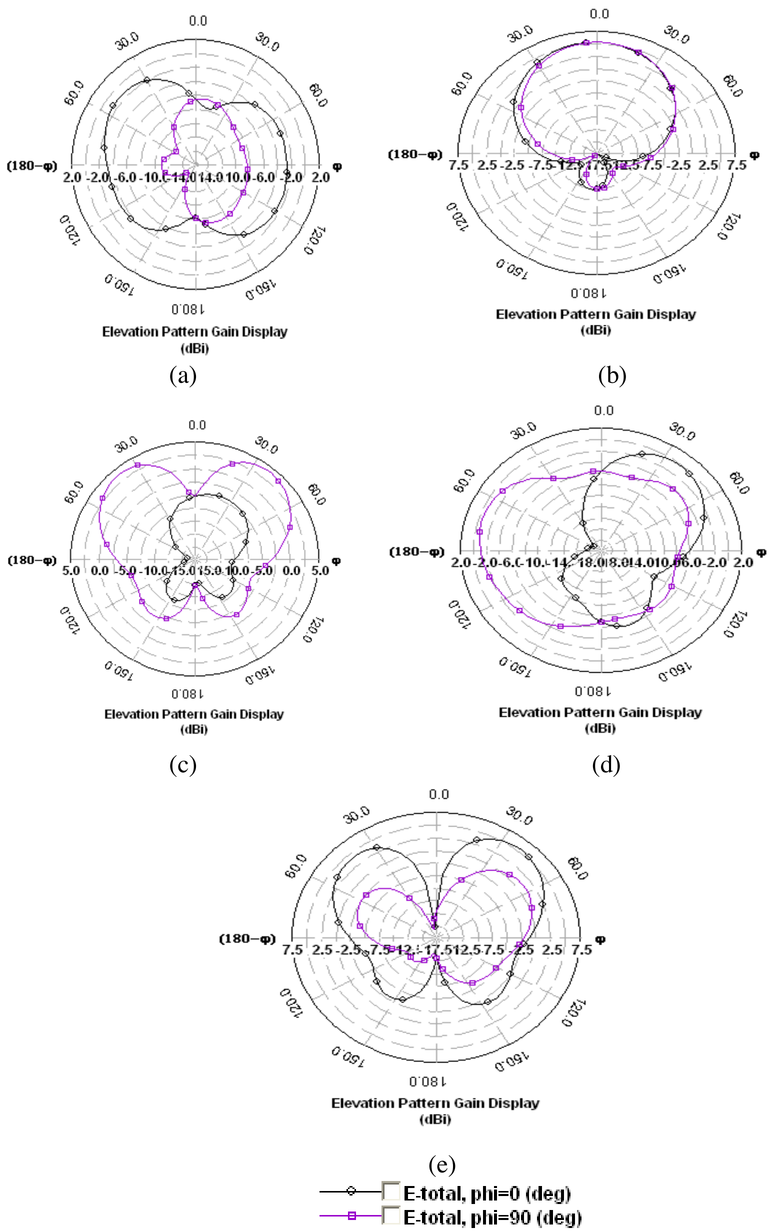
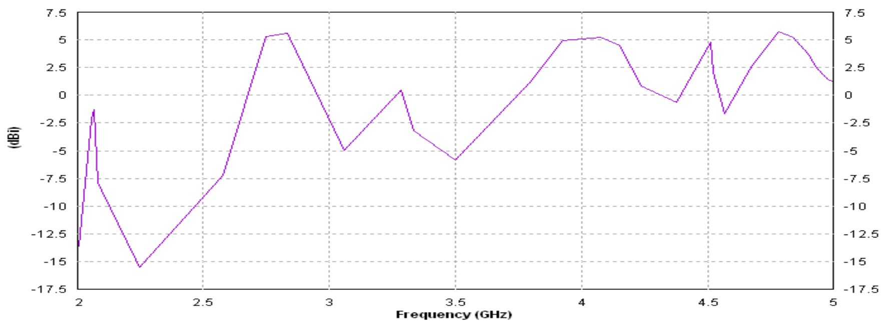
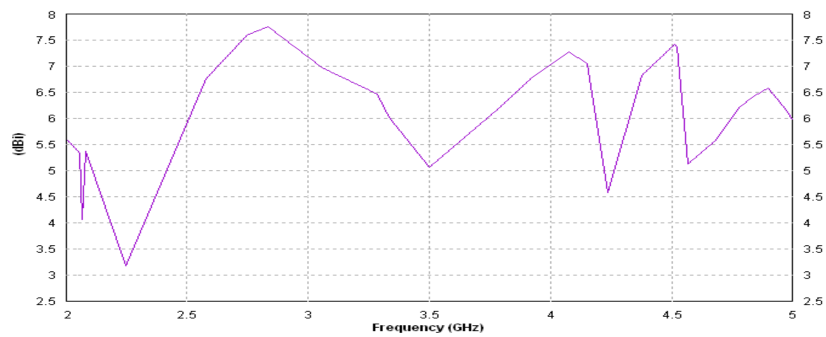


Figure 4. Radiation pattern of E-fields in the $\varphi = 0°$ and $\varphi = 90°$ planes at different resonant frequencies, (a) $f_r = 2.0675\,\text{GHz}$, (b) $f_r = 2.7875\,\text{GHz}$, (c) $f_r = 4.2050\,\text{GHz}$, (d) $f_r = 4.5125\,\text{GHz}$, (e) $f_r = 4.7825\,\text{GHz}$.



(a)



(b)

Figure 5. Behaviors of the gain (a) and directivity (b) of the proposed antenna as a function of frequency.

switches for the multi-wideband operation. Five resonant frequencies in the frequency range with RL less than -9.54 dB are obtained. The variation of VSWR with frequency shows that it is ≤ 2 at the resonant frequency bands corresponding to a RL less than -9.54 dB.

Figure 4 shows the radiation patterns of the $|E|$-field in the $\varphi = 0$ and $\varphi = 90$ planes for the proposed antenna at different resonant frequencies. Wide variations of the radiation pattern are obtained. The results show that the radiated power in the back loops is small compared to the forward radiated power at the frequencies 2.7875, 4.205, and 4.7825 GHz. The advantage of reducing radiation from back loops is necessary to minimize the electromagnetic power radiated back to the heads of the headsets users. The gain and directivity of the proposed antenna are shown in Figs. 5(a) and 5(b), respectively. The behaviors of the antenna and radiating efficiencies are presented in Fig. 6. The computed results in Figs. 5 and 6 illustrate that

Figure 6. Behaviors of the antenna and radiation efficiencies of the proposed antenna with frequency.

the proposed antenna has a high gain and directivity. Its radiation efficiency is higher than 90% over the operated frequency range. Moreover the proposed antenna provides an enhancement of multi-wideband operation. Those advantages of the antenna benefit different applications.

4. CONCLUSION

A new reconfigurable compact microstrip antenna of operating frequencies in the range of 2–5 GHz with return loss less than -9.54 dB is presented. Two switches are integrated into the slots of the conventional rectangular patch antenna with parasitic and slots in order to enhance and control the frequency bands. It has been illustrated that the behavior of the return loss in the frequency range 2–5 GHz is better at a certain state of the two switches. The suggested design gives more resonant frequency bands with reasonable frequency bandwidths compared with the conventional antenna in the literatures. The positions and dimensions of the parasitic, slots and switches of the newly multi-wideband patch antenna are optimally chosen to give as many wide resonant frequencies as possible.

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