UWB Antenna with Optically Controlled Notches

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Abstract— This paper presents an UWB antenna with optically controlled frequency notches. Behavior of the photoconductive optical switches under light illumination and in the dark are modeled. The optical signal in turn alters the radiation properties of the antenna structure and consequently changes the notched frequency bands. This antenna achieves reconfigurable frequency pass bands with high gain and controlled rejected bands with low radiation efficiency.

1. INTRODUCTION

In recent years, reconfigurable antennas have received a great attention for wireless communication system. Antenna parameters as frequency, radiation pattern and polarization are reconfigured. Frequency reconfigurable antenna supports multiple functions at multiple frequency bands and reduces the hardware size and cost [1]. Switches such as RF pin diodes or varactor diodes are commonly used to achieve frequency reconfigurability [2]. Several design on reconfigurable antenna have been reported in [3–7]. In the proposed UWB antenna, there is an inverted U-slot with four switches on the patch side. Frequency-band reconfigurable capability is achieved by using a switchable slotted structure on the inverted U-slot. Photoconductive switches are used because of their superior performance as compared to MEMS, p-i-n diodes, and lumped elements. The photoconductive approach does not require the use of bias lines, which typically lie in the plane of the antenna and can interfere with the electromagnetic performance of the antenna. Also photoconductive switches exhibit extremely fast switching speeds on the order of nanoseconds [4]. Such a construction allows for easy integration of such antenna designs into conformal packaging for wireless devices [4, 8].

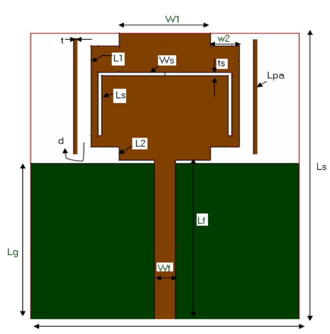


Figure 1: The original UWBA.

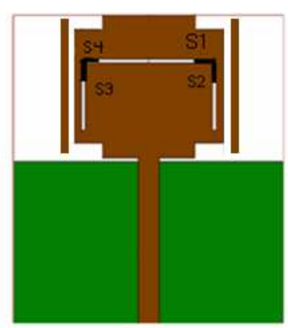


Figure 2: Four optical switches are inserted at the corner of inverted U-slot.

Table 1: Dimensions of the proposed antenna.

Parameters	W_1	W_2	W_f	W_s	L_1	L_2	L_s	L_g	L_f
Value (mm)	13	4	3	38	16	2	47	26.5	27

Table 2: Parameters of inverted U-slot and parasitic element.

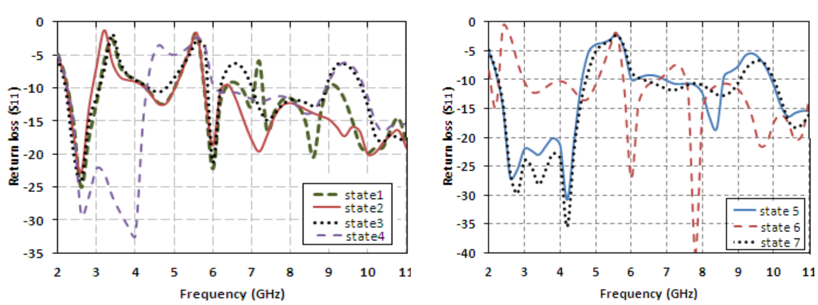
Parameters	L_s	W_s	t_s	L_{pa}	T	d
Value (mm)	10	19	0.5	19	0.5	0.25

Table 3: The states of the switches.

States	Radiation efficiency %	Maximum Gain (dBi)	Notched frequency (GHz)
State 1, S_1 ON	96.17%	6.49	(3 : 4) and (5.02 : 5.8)
State 2, S_2 ON	98.47%	6.42	(2.93 : 4.24) and (5.02 : 5.7)
State 3, S_1 & S_2 ON	98.69%	6.65	(3.12 : 4.44) and (4.74 : 5.88)
State4, S_2, S_3 & S_4 are ON	98.50%	6.63	(4.32 : 6.06)
State 5, S_1, S_3 & S_4 are ON	98.68%	6.46	(4.62 : 6.18)
State 6, all are OFF	97.22%	6.11	(2.28 : 2.98) and (5.06 : 5.8)
State 7, all are ON	98.61%	6.55	(4.47 : 6.18)

2. STRUCTURE OF THE PROPOSED ANTENNA

The ultra wide band antenna that consists of rectangular patch fed by a microstrip line with a partial ground is shown in Figure 1. The antenna is design on FR-4 substrate ($\varepsilon_r = 4.4$, $h = 1.6$ mm, $\tan\delta = 0.025$) and the dimensions are listed in Table 1. Parameters of inverted U-slot and parasitic elements are listed in Table 2. As shown in Figure 2 four switches S_1, S_2, S_3 and S_4 are inserted and optically controlled. The photoconductive switches are activated by laser light that is coupled through an optical fiber which extends from the ground plane to just underneath the silicon element (silicon filled gaps) placed on the radiating face of the antenna structure. The equivalent circuit of the gap with laser and in the absence of laser (dynamic gap resistance) are calculated using the equations in reference [9].



(a) (b)

Figure 3: Simulated return loss for different states of the switches.

3. ANTENNA RESULT

3.1. Return Loss

The simulated return loss in different cases of the optical switches are shown in Figures 3 and 3(b) and are listed in Table 3.

3.2. Radiation Pattern

Radiation pattern at the center frequency of the rejected bands for different states of switches are shown in Figure 4.

3.3. Current Distribution

Figures 5 and 6 represent the surface current distribution for states 6 and 7 at resonant and at notched frequencies. Figure 5 shows the surface current distribution of the proposed antenna at the resonant frequency (7.7 GHz) and center frequencies of the rejected bands (2.4 GHz and 5.6 GHz).

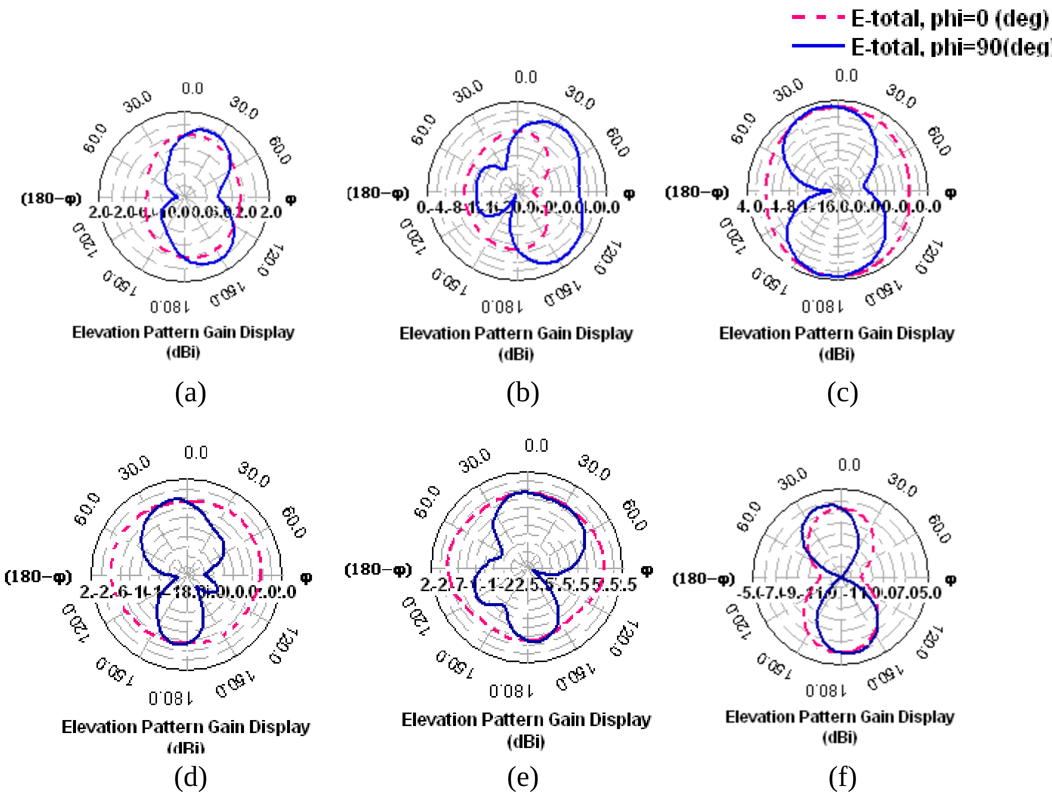


Figure 4: Simulated return loss for different states of the switches.

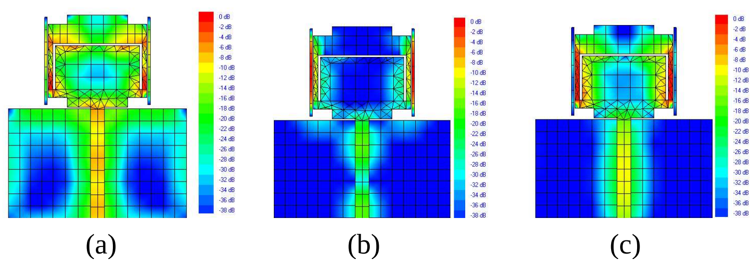


Figure 5: Current distribution for state 6: (a) (at 7.7 GHz), (b) (at 5.6 GHz), and (c) at 2.4 (GHz).

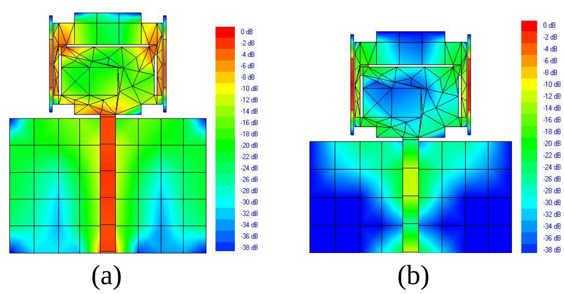
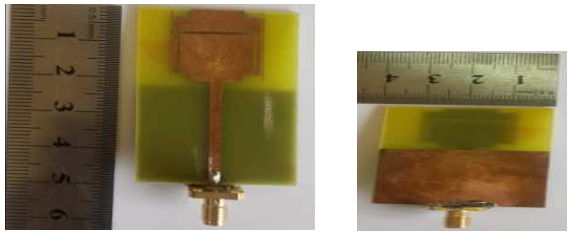


Figure 6: Current distribution for State 7: (a) (at 4.2 GHz) and (b) (at 5.6 GHz).

Figure 6(a) illustrates a continuous path of the feeder current at (7.7 GHz) and a rejected band at (at 5.6 GHz).

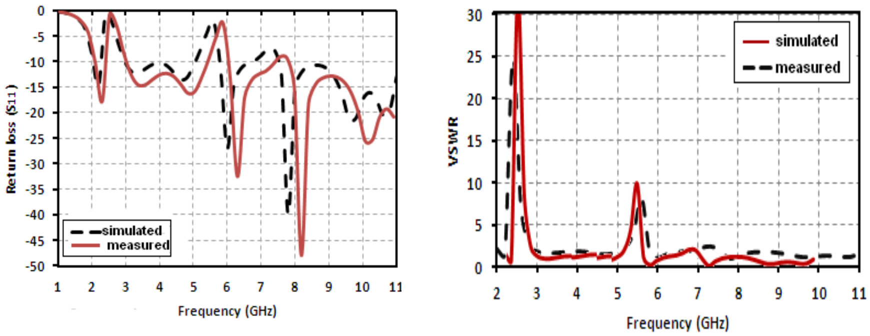
4. SIMULATED AND MEASURED RESULT

The fabricated UWBA having inverted U-slot with gaps and parasitic elements is shown in Figure 7. The return loss and VSWR were compared with the simulated results in case of state 6 as shown in Figures 8(a) and 8(b). Experimentally measured RF performance of the antenna is in good



(a) (b)

Figure 7: Photograph of the fabricated antenna. (a) Top view. (b) Bake view.



(a) (b)

Figure 8: Simulated and measured results for state 6: (a) return loss and (b) VSWR.

agreement with the simulations results.

5. CONCLUSIONS

An UWBA with reconfigurable frequency notch is presented. The antenna operates at multi-bands to support several wireless communication systems. Frequency reconfigurablility of this antenna is achieved using optically controlled switches. The antenna provides high gain during the pass band frequencies and low gain through the rejected bands. Experimental measured performance well agree with the simulations results. Such a construction of optically controlled antenna can be easy integrated into conformal packaging for wireless communication devices.

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