# A RECONFIGURABLE DUAL-FREQUENCY SLOT-LOADED MICROSTRIP ANTENNA CONTROLLED BY PIN DIODES

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**ABSTRACT:** *A novel reconfigurable, single-feed, dual-frequency, dual-polarized operation of a hexagonal slot-loaded square microstrip antenna is presented in this paper. A pin diode incorporated in the slot is used to switch the two operating frequencies considerably, without significantly affecting the radiation characteristics and gain. The proposed antenna provides a size reduction up to 61% and 26% for the two resonating frequencies, compared to standard rectangular patches. This design also gives considerable bandwidth up to 3.3% and 4.27%, for the two frequencies with a low operating frequency ratio.* © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 44: 374–376, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20639

**Key words:** *microstrip patch antenna; dual frequency; reconfigurable; pin diode*

## 1. INTRODUCTION

Dual-frequency microstrip antennas generally have wide applications in mobile satellite personal communication systems, GPS, cellular network systems, and so forth. Reconfigurable microstrip antennas can be used to cover these multiple functions with a single antenna aperture. Single-feed patch antennas with a switchable slot, controlled by pin diodes, and capable of dual-frequency operation have been reported recently [1, 2]. A hexagonal slot-loaded square microstrip antenna with dual-frequency operation and orthogonal polarization has also been demonstrated [3]. In this paper, we demonstrate a novel compact, single-feed reconfigurable dual-frequency square microstrip-patch antenna, embedded with a hexagonal-shaped slot, having a switchable extended arm for dual-frequency operation and enhanced area reduction. A pin diode is placed at the extended slot arm to change the electrical length of the slot and thus shift the two resonant frequencies considerably in different states of the diode. This new design uses a simplified biasing circuitry with a very low bias voltage. Also, the proposed design provides a greater area reduction and bandwidth enhancement, as compared to conventional microstrip patch antennas. It is also worthwhile to note that the frequency shift in this design is considerably high and flexible. Another attractive feature is that the antenna shows almost similar radiation patterns at all the four operating frequencies without significant reduction in gain. The design has been successfully implemented and the experimental results are presented.

## 2. ANTENNA STRUCTURE AND DESIGN

The geometry of the proposed reconfigurable microstrip patch antenna with hexagonal slot is illustrated in Figure 1. A square microstrip-patch antenna with side dimension $L$ is fabricated on a substrate of thickness $h$ and relative permittivity $\varepsilon_r$. A hexagonal slot of side parameters $l_1$ and $l_2$ with a slot arm of length $l_a$ and width $w_a$ extending up to the edge of the square patch is placed at its center. A pin diode $D$ is positioned at the slot arm, 0.5-mm below the square patch side in order to obtain the maximum frequency shift for both resonant frequencies. A capacitor $C$ and a narrow slit are used for DC isolation. DC bias voltage is supplied from a battery via two chip inductors. The antenna is electromagnetically coupled using a microstrip line, as shown in Figure 1.

The extended slot arm splits the fundamental resonant frequency of the square microstrip patch, with a hexagon alone, into two separate resonant modes ($TM_{10}$ and $TM_{01}$) with orthogonal polarization planes. These two excited frequencies can be tuned by

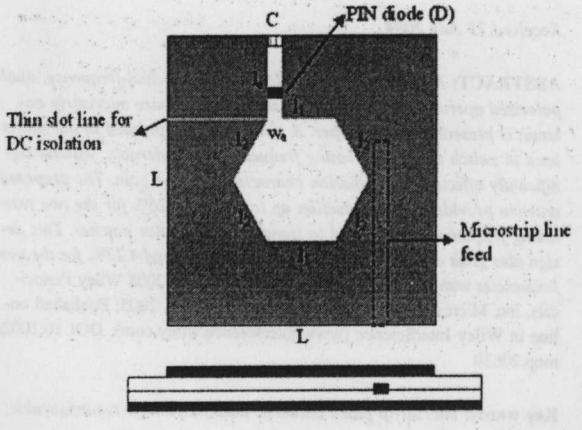


**Figure 1** Geometry of the proposed reconfigurable antenna controlled by pin diode (antenna parameters are given in Fig. 2)

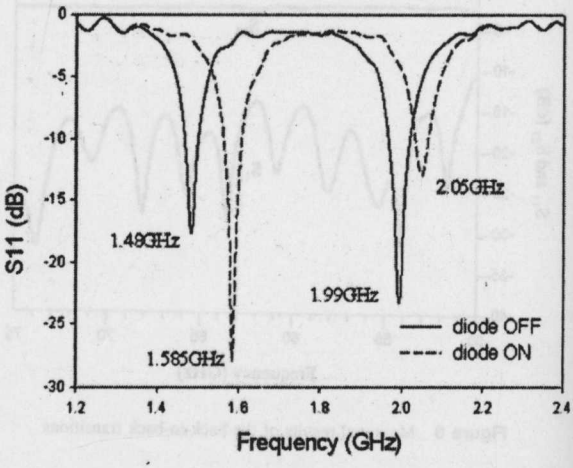


**Figure 2** Measured return loss of the antenna with pin diodes in ON and OFF state. ($L$ = 4 cm, $l_1 = l_2$ = 0.8 cm, $l_a$ = 1.1 cm, $w_a$ = 0.1 cm, $h$ = 0.16 cm, and $\varepsilon_r$ = 3.98)

changing the slot-arm length. When the pin diode is ON, it essentially behaves as an equivalent short circuit, thus driving the currents on the patch directly through it, and reducing the effective length of the slot. When the diode is switched OFF, the currents have to flow through the capacitor $C$, with an increased current path, resulting in the shifting of resonant frequencies towards the lower-frequency region. The position of the pin diode is selected so that good matching is obtained for all the four excited frequencies. The newly designed antenna achieves good return-loss characteristics and bandwidth, even when the position of the diode is altered to achieve the desired frequency values.

To obtain correct biasing of the diode, the slot arm is open at one end with a small smd capacitor soldered in order to block the DC bias current and provide good RF continuity. A narrow slit is designed at the bottom of the slot arm in order to switch the diode properly, without affecting the patch currents.

## 3. EXPERIMENTAL RESULTS

The fundamental resonant frequency of the unslotted square patch is 1.885 GHz. By embedding the hexagonal slot and the extended arm, two lower resonant frequencies can be excited due to the increase in the effective lengths of the two resonant modes ($TM_{10}$ and $TM_{01}$) of the square patch.

When the diode is switched OFF, the antenna resonates at 1.48 and 1.99 GHz with a frequency ratio of 1.34. Once the diode is turned ON, the first resonant frequency shifts to 105 MHz and second resonant frequency to 60 MHz, thus giving excitation at 1.585 and 2.05 GHz, respectively, with a frequency ratio of 1.29. In all these four operating frequencies, the antenna has good matching at a single feed position. Figure 2 shows the measured return loss ($S_{11}$), of the antenna with dimensions $L$ = 4 cm, $l_1 = l_2$ = 0.8 cm, $l_a$ = 1.1 cm, $w_a$ = 0.1 cm, $h$ = 0.16 cm, and $\varepsilon_r$ = 3.98. The frequency ratio is tunable in the range 1.2684 to 1.3137 in the ON state and 1.3227 to 1.3779 in the OFF state by changing the diode position along the slot arm, thus realizing an added advantage of flexible frequency tuning.

The new design provides an area reduction of 61% for the first resonant frequency and 26% for the second, as compared to the standard rectangular patch antenna. Bandwidths up to 3.3% and 4.27% respectively, have been obtained for the two modes, in ON and OFF states.

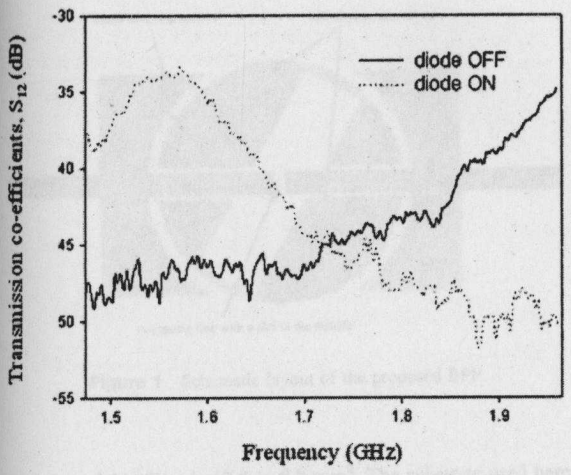


**Figure 3** Variation of received power with frequency for the two orthogonal polarization planes for both diode states

The transmission characteristics ($S_{12}$) of the designed antenna in two orthogonal polarization planes for different diode states are shown in Figure 3. The polarization planes of the two resonant frequencies are mutually orthogonal in both states of the pin diode. The radiation patterns are measured for the ON and OFF states of the diode, as shown in Figure 4. All the patterns show similar broadside-radiation characteristics with better cross-polarization levels. The gain of the antenna is 1.3-dB less than that of the standard circular patch when the diode is OFF and nearly 2-dB less when the diode is ON.

## 4. CONCLUSION

A novel single-feed patch antenna with reconfigurable dual-frequency operation and orthogonal polarization has been presented in this paper. The proposed antenna can radiate four frequencies altogether with almost similar radiation patterns. The proposed antenna gives a size reduction up to 61% and 26% for the two resonating frequencies, as compared to standard rectangular patches. Also, it gives considerable bandwidth up to 3.3% and 4.27%, for the two frequencies with a low operating-frequency

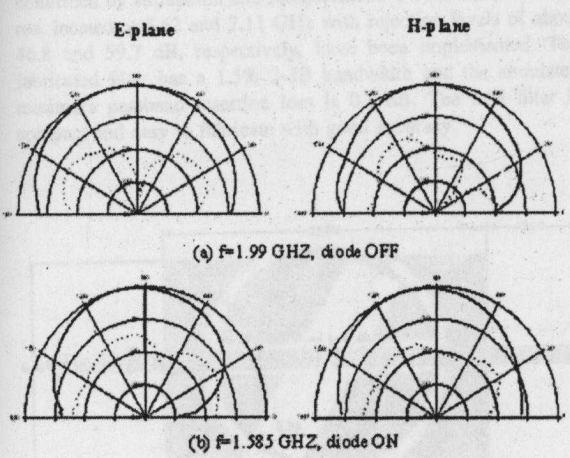


**Figure 4** Measured E-plane and H-plane radiation patterns of the proposed antenna in the diode OFF and ON states

ratio in the ON and OFF states of the pin diode without significant reduction in gain.

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