A Multi-Functional Stacked Patch Antenna for Wireless Power Beaming and Data Telemetry

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Abstract

A multi-functional stacked patch antenna is introduced for possible wireless power beaming and data telemetry application. The proposed antenna operates at 5.8 GHz with 10 dBi gain, and 18% bandwidth. At a lower frequency at around 2.45 GHz the antenna operates as a planar inverted-F antenna (PIFA) with 4 dBi gain and 3.2% bandwidth. Switching between the two regimes of operation can be achieved using PIN diodes. It is proposed that the antenna can be used for wireless power reception in sensors at 5.8 GHz and for data telemetry in between sensors or a sensor and a control station at 2.45 GHz.

Introduction

Multifunctional antennas are becoming increasingly popular in defense and commercial wireless applications since a single aperture can be used to support multiple functions at separate frequency bands. A microstrip antenna was reconfigured using MEMS switches in [1]. The geometry of the antenna was subdivided and MEMS switches were positioned at different locations of the antenna to change the resonant frequency. A reconfigurable patch antenna with switchable slots using PIN diodes was introduced in [2]. Stacked reconfigured bow-tie elements were proposed by Bernhard *et al.* [3] for space based radar applications.

In this paper we introduce a multi-functional stacked square microstrip patch antenna that can function as a wideband, high gain patch antenna for wireless power reception in sensors at one frequency and as a data telemetry antenna for another frequency band for communication in between sensors or a sensor and an interrogator. Earlier we proposed a reconfigurable antenna for dual-frequency operation for satellite communication and land mobile radio at 2 GHz and 450 MHz, respectively [4].

Antenna Design

The geometry of the proposed antenna is shown in Fig. 1. It consists of two square patches, Patch1 and Patch2 with lengths of 13 and 17 mm, respectively. Patch1 is printed on a relatively thin ($h_1=1.5$ mm) substrate with dielectric constant $\varepsilon_{r1}=3.38$. Patch2 on the other hand is on top of a generally thicker ($h_2=4.5$ mm) low dielectric constant Rohacell foam ($\varepsilon_{r2}=1.04$). Ground plane size is 60 mm by 60 mm. Pin1 and Pin2 (cylindrical pin with radius of 0.25 mm) are positioned at the left edge of Patch2 and vertically connected or disconnected to the ground by the PIN diode control circuits. The distance between these two pins is 5.5 mm. Feed2 is fed 1 mm away from the left edge of

Patch2. Feed1 fed Patch1 through the 50 Ω microstrip line. The two modes of this antenna work like this: when Feed1 is activated, Feed2 and the shorting pins (Pin1 and Pin2) are in the “off” state. Since Patch1 (fed by Feed1) and Patch2 are electro-magnetically coupled to each other, the antenna functions as a stacked microstrip patch. In this regime the antenna radiates broadside to its axis, has high gain and wide impedance bandwidth. On the other hand, Feed2 is activated and the two shorting pins are connected to the ground the antenna operates as a planar inverted-F antenna (PIFA) which has a pattern directed to the axis of the antenna, reasonable gain, and good for terrestrial mobile or data links.

Results

Computed S11 (dB) data for the proposed antenna are shown in Fig. 2. Simulations were performed using Ansoft HFSS. Antenna bandwidth in the stacked patch regime extends from 5.45 to 6.53 GHz (18%). The same in the PIFA regime extends from 2.41 to 2.49 GHz (3.2 %). Figs. 3 (a) and (b) depict the normalized radiation patterns for the stacked patch at 5.8 GHz. The peak gain is 10 dBi. Clearly in both planes the antenna radiation beam is directed broadside to its axis and the beamwidth is narrow enough to ensure high gain. Figs.4 (a) and (b) show the patterns for the PIFA at 2.45 GHz. The patterns are very similar to standard PIFA patterns. It is understandable that the ground plane size at 2.45 GHz is electrically small and hence the radiation patterns are close to being uniform. The peak gain of the PIFA at 2.45 GHz is 4 dBi. The antenna has excellent upper hemispherical and azimuthal coverage suitable for terrestrial communications. The PIN diode control circuits are illustrated in Fig. 1 (c). The control circuits are on the same layer as patch1 and are placed on RO4003 substrate. Feed1 and Feed2 have their individual control circuits. Since pin1 and pin2 are similar (on or off at the same time), they share a single control circuit. These circuits are currently being investigated the results of which will be presented during the conference.

Conclusions

The study and design of a stacked reconfigurable microstrip patch antenna are presented. Using PIN diode switches it has been demonstrated that a stacked microstrip antenna can be reconfigured to support two distinctly different operating frequency bands with varying bandwidth and pattern requirements. The stacked patch design presented in this paper at 5.8 GHz has an impedance bandwidth of 18% and 10 dBi peak gain. Thus this antenna is clearly good for wireless power reception in sensors. When stacked patch mode is de-activated and the antenna is in the PIFA regime working at 2.45 GHz with impedance bandwidth of 3.2%, the radiation patterns are directed towards the upper hemisphere with peak gain of 4 dBi and strong azimuthal pattern coverage. The PIFA mode is suitable for wireless data communication between sensors or sensor and a control station.

Acknowledgement

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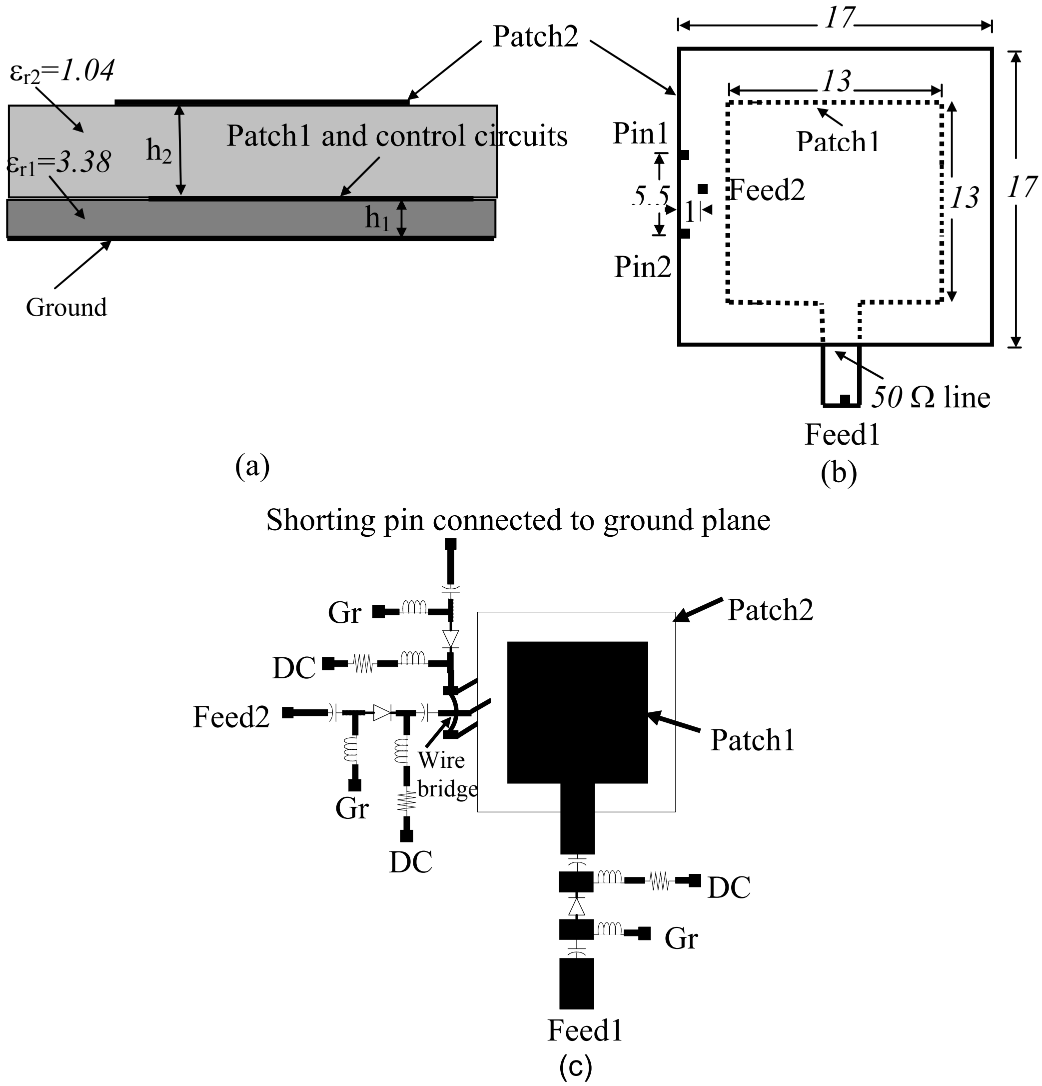
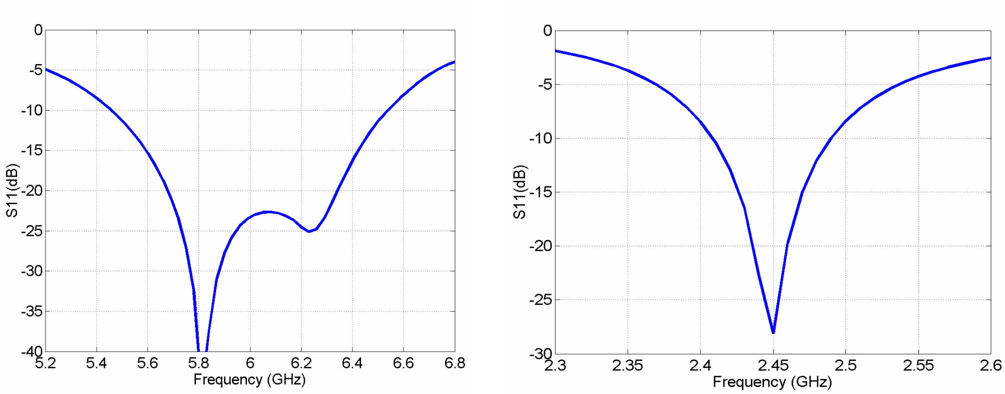
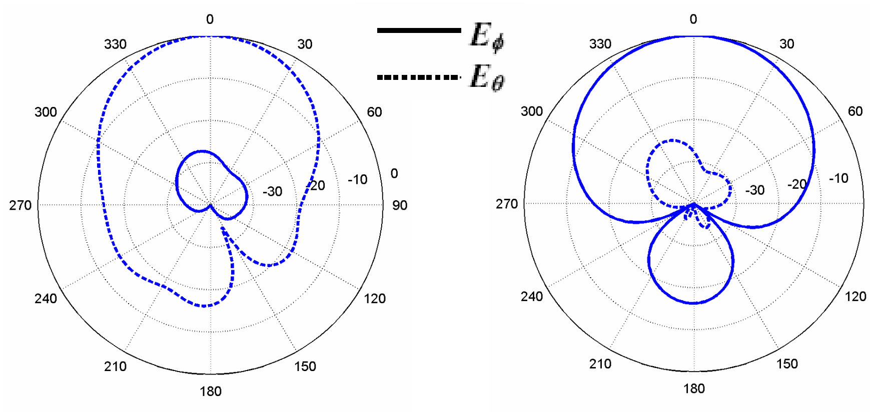


Figure 1: (a) Different layers, (b) top view of the proposed antenna, and proposed (c) PIN diode control circuits. All dimensions in mm.



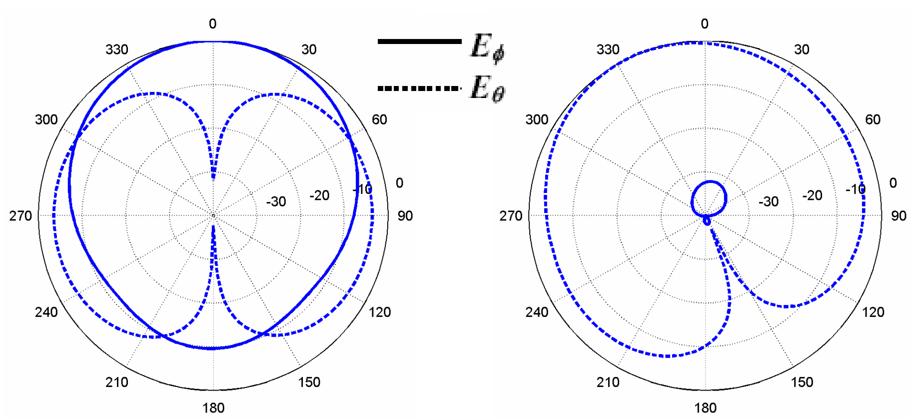
(a) (b)

Figure 2: Computed S11 versus frequency for (a) stacked patch mode, and (b) PIFA mode.



(a) (b)

Figure 3: Computed normalized radiation patterns at 5.8 GHz for stacked patch mode (a) φ=0^0, (b) φ=90^0.



(a) (b)

Figure 4: Computed normalized radiation patterns at 2.45 GHz for PIFA mode (a) φ=0^0, (b) φ=90^0.