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Development and Experimental Measurements of a Tunable Antenna

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ABSTRACT

Modern telecommunication systems need to be equipped with antennas that are precisely tuned to more than one frequency in order to allow operation in several bands. Antenna precise tuning to the desired frequency is very important for system performance. In this paper the operating frequency of a PIFA antenna is adjusted using a varactor. This configuration has the advantage of continuous tuning, thus correcting any frequency deviation due to environmental or other changes. The PIFA antenna's tuning ranges from 860 MHz to 1025 MHz. Also, the geometry of the antenna is studied through simulations and the effect of the varactor is tested experimentally.

Keywords: PIFA; Mobile Antenna; Varactor; Frequency Tuning

1. Introduction

Many emerging techniques [1-5] are parts of wireless telecommunication systems. These systems are characterized by their most essential elements which are antennas. The use of the proper antenna leads to effective propagation of electromagnetic energy from the transmitter to the receiver through the wireless channel. Planar antennas present significant advantages over conventional antennas such as monopoles or helical antennas: low cost, low profile and reduced backward radiation towards user's head [6].

The Planar Inverted F Antenna (PIFA) is widely used in the mobile phone market due to its low profile, small size, and built-in structure. Other major advantages are easy fabrication, low manufacturing cost, and simple structure. It has narrow bandwidth in contradiction to UWB antennas [7], and presents moderate to high gain in vertical and horizontal polarization. The PIFA consists of a ground plane, a top plate element, a feed wire feeding the resonating top plate, and a shorting pin that is connecting its radiating patch to the antenna's ground plane [8-10].

We can modify a PIFA antenna to operate over multiple frequency bands using various methods. For example, we can use parasitic antenna elements and/or slit the antenna element to form different paths for surface currents [11,12]. Modified PIFA structures can cover the frequency range of six telecommunication standards [13].

We can tune the operating frequency of a PIFA either mechanically or electrically. The electrically reconfigurable tuning method is relevant to changing the electrical length of the antenna. This can be conducted using a short circuit connection with an external tuning circuit [14,15]. Other tuning methods, that have been reported, include the use of an adjustable reactive component between the PIFA patch [16,17] and the ground plane, or switched tuning stubs, which have been applied in both single-band and dual-band PIFAs [18].

In this paper the feeding point position, the height of the antenna, the shorting strip position, the short capacitor place have all been studied in detail. The influence of the short capacitor value to the resonant frequency is simulated and experimentally measured in a proposed structure antenna ideally used for GSM band.

This paper is split into four sections. In the second section details are given about the antenna structure and design process. The corresponding simulated and measured results for return loss and radiation patterns are presented and discussed in the third section. Finally, conclusions are given in the fourth section.

2. Structure Design

Figure 1 shows the geometry of the antenna. The features of the design include offset short strip and capacitive loads which are illustrated. The ground plane and the top patch layer lie over a dielectric layer with electric permittivity (ε_p = 4.4) and 1.5 millimeters thickness. The top patch layer and the ground plane layer have a space described by the variable *h*. The width (W_g) of ground plane is 26.4 mm and the length (L_g) is 66 mm. The dimensions of patch layer are ($W \times L$) = 26.4 mm × 14.5 mm.

The RF signal is fed to the top patch layer through an SMA female panel mount connector. The SMA connector's dimensions are equal to commercial standards. The width of strip feed is W_f and is L_f mm away from the angle noticed by the number 1 as showing in **Figure 2**. The top patch and ground plane are shorted together by a shorting strip that has a width of W_s. The feed strip and shorting strip are spaced apart L_b mm away. For AC coupling we have placed two capacitors C_1 and C_2 to the feed and shorting strips.

The varactor is placed on a PCB which is L_{bc} mm away from the corner noticed with *No.* 1 (**Figure 1**). The PCB is vertically to the top and to the ground plane and is constructed by the same material as the top and ground plane. The dimensions of this PCB are: ($L_c \times h$). The varactor is L_{uc} mm away from the corner *No.* 2 (**Figure 3**). Also, we have placed three other electronics components (L_1, L_2 and C_3) on this PCB.

The variables which describe the geometry of the antenna are presented in **Table 1**.

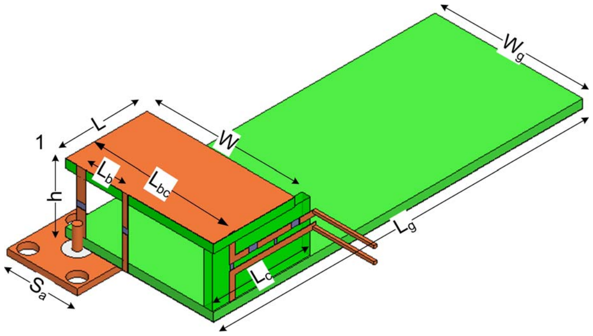

Figure 1. PIFA schematic.

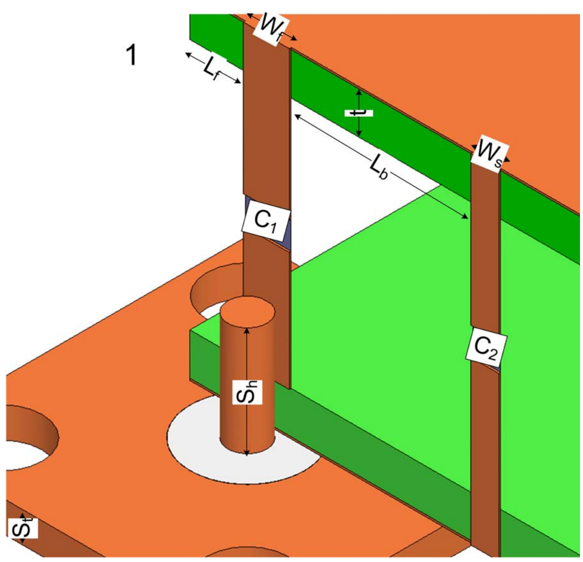

Figure 2. Schematic details with feed and short strips.

Varicap Driven Circuit

Varactor SMV1232 [19] is used as a variable capacitance. The main characteristic of the varactors is that the capacitance is inversely proportional to the square root of

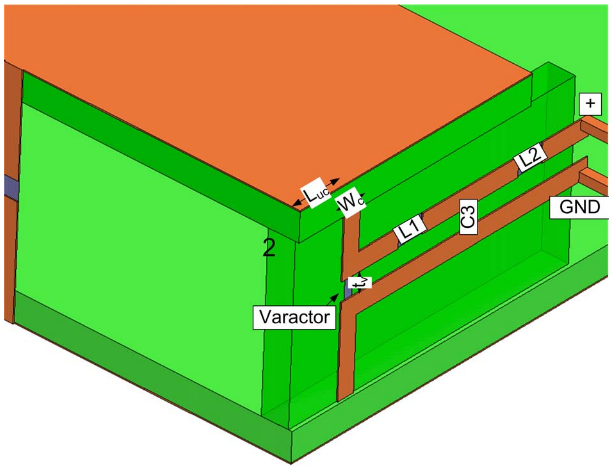

Figure 3. Topology of the varactor circuit.

Table 1. Antenna parameters.

Parameter	Value (mm)
L_g	66.0
W_g	26.4
L	14.5
W	26.4
t	1.5
h	12.0
L_{bc}	26.4
L_c	17.5
S_a	12.5
S_h	5.0
S_t	1.1
W_f	1.6
W_s	1.0
W_c	1.0
L_b	6.5
L_f	2.0
L_{uc}	3.0

the applied voltage. **Figure 4** depicts the circuit that is used to the studied PIFA. To ensure DC insulation between top patch and ground plane in feed and short strip, we placed one capacitor to each strip (**Figure 5**). The values of the inductances and capacitance are shown in **Table 2**.

Figure 6 shows the constructed antenna with the DC feed cable attached to the varactor driven circuit.

3. Analysis and Results

An antenna was fabricated using printed circuit techniques in order to test its performance and to study the effect of the value of the varactor. The purpose was to investigate the role of the variable capacitance in the resonance frequency. Simulations included the use of frequency domain calculations of the electromagnetic equations utilizing the method of moments. The simulated return loss is presented in **Figure 7**.

For measurement purposes, a network analyzer (Anritsu MS4624B) was used. We evaluated the performance of the antenna by measuring the reflection coefficient S_{11}. **Figure 8** shows the results. It is observed that the PIFA dynamic bands (−10 dB return loss band) can be tuned from 810 MHz to 1050 MHz and as we can see, by increasing the bias voltage (the capacitance decreases), the resonant frequency increases. The previous constitute a good agreement between simulated and measurement results.

Three antennas were constructed in order to examine the effect of the height (h). The respective heights of the antennas were: 15.3 mm, 14.3 mm and 12.0 mm. Additionally we changed the bias voltage of the varactor from 0 to 15.5 Volt. The results of the network analyzer for the reflection coefficient are presented in **Figure 9**. It is clearly shown that by increasing the bias voltage on the varactor the resonant frequency of the antenna decreases. Also, a very important fact is that by altering the height

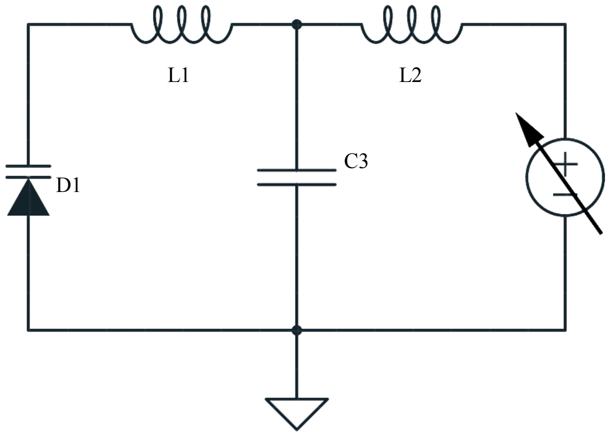

Figure 4. The varactor driving circuit.

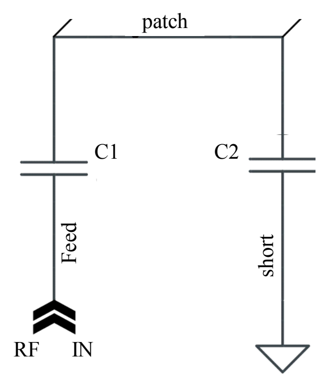

Figure 5. The feed and short strips for AC coupling circuit.

Table 2. Electronic Elements

Part	Value
L_1	47 nH
L_2	47 nH
C_1	100 nF
C_2	100 nF
C_3	15 pF

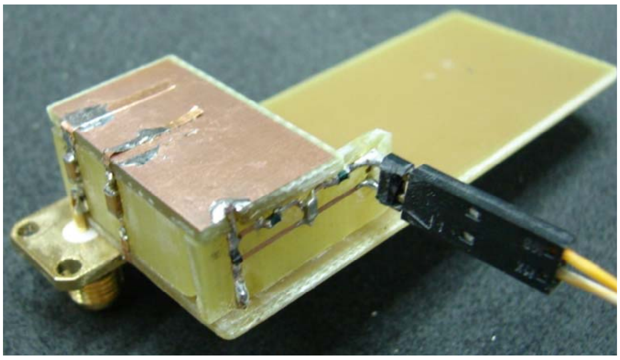

Figure 6. Prototype of the proposed PIFA.

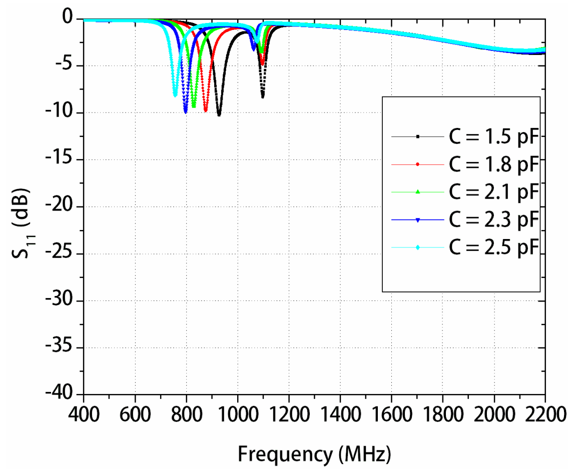

Figure 7. Simulated results.

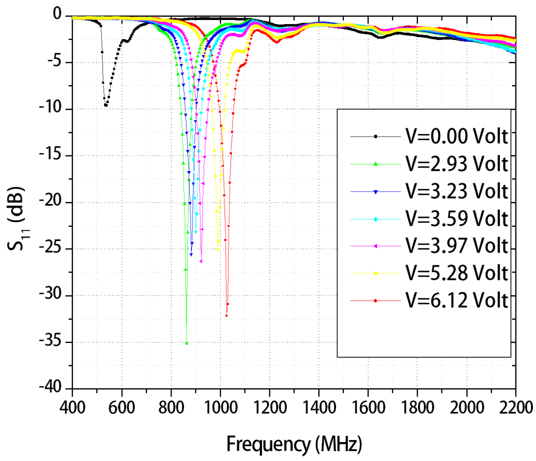

Figure 8. Reflection coefficient versus bias voltage of the varactor.

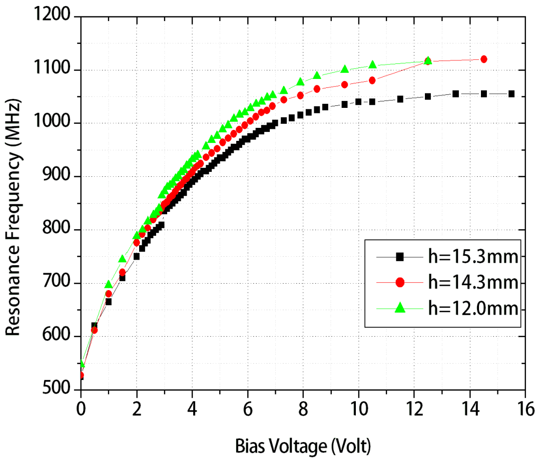

Figure 9. Measured return loss (S_{11}) of antennas versus bias voltage on varactor, for various antenna's height (*h* = 15.3, 14.3 and 12.0 mm).

of the antenna, it is possible to reconfigure the resonance frequency at a predefined frequency, by changing the bias voltage of the varactor. This result is very important since it concludes to smaller antenna sizes without changing its electrical characteristics.

4. Conclusion

In this article a Planar Inverted F Antenna for mobile applications was designed, fabricated and tested. The effect of the voltage value of a varactor at the resonance frequency of the antenna was thoroughly investigated. The impact of the additional variable capacitance was simulated using the method of moments and compared with the experimental measured results. The impact of the height, a basic parameter of the antenna's dimension was also investigated. The experimental results show that we can reduce the physical size of the antenna by changing the applied voltage on the varactor. Through this study we conclude that we can achieve a decrease of the size of the PIFA without losing the electrical performance of the antenna.

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