A novel PIFA type varactor tunable antenna with U-shaped slot

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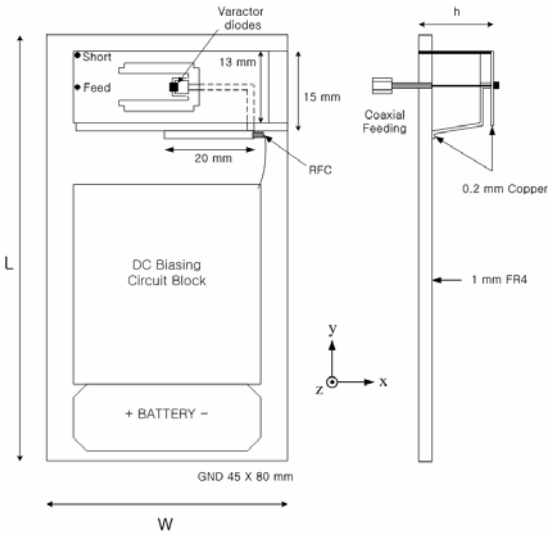
Abstract

A planar inverted-F antenna type tunable antenna with U-shaped slot is proposed. A varactor diode is integrated between the slot and bias feeding strip line for tuning the operating frequency. This antenna covers from 1.64GHz to 2.05 GHz refer to the dc bias voltage from 0V to 20V. The frequency tuning range is about 410 MHz bandwidth which covers several mobile communication bands of DCS(1710~1880MHz), PCS(1750~1870MHz) and PCS(USA)(1850~1990MHz). This antenna occupies a compact volume of 40 x 15 x 8 mm^3. The simulation result is based on the Finite Integral Method.

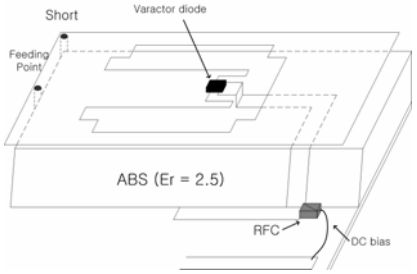
1. Instruction

Recently, tunable antennas have been studied using several techniques such as RF switch, PIN diodes, and MEMS switches [1]~[3]. Varactor diode is one of important tuning technique with the advantages of large capacitance ratio, small size, and a resonant frequency can be changed by dc voltage control[4]. A PIFA type antenna[5] is very suitable structure by incorporating varactor tuned antenna even though it has relatively narrow operation bandwidth. Since varactor tuned antenna uses dc bias circuit, two dc block capacitors are usually needed. In PIFA structure, the antenna shorting pin is already connected to ground plane, one of dc block capacitors can be removed. This fact results into achieving a small volume of antenna size that is enough small to be included in mobile handset. This paper presents a new varactor tuned PIFA type slot antenna covering DCS and PCS, PCS(USA) bands with achieving a frequency tuning range of 410 MHz, 22.16% of tenability range. The fabricated antenna is compared with the measured result and the simulated one preformed by CST Microwave Studio.

2. Antenna Design



(a)



(b)

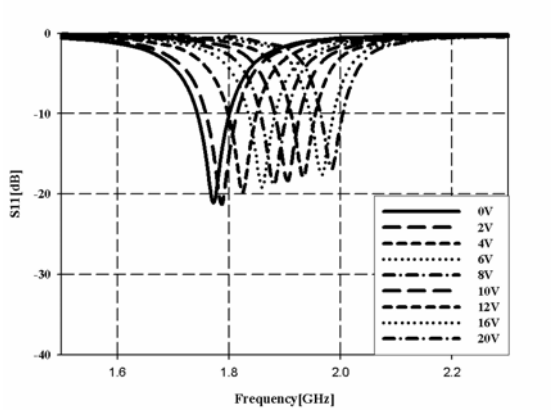
(c)

Fig. 1 Geometry of the proposed antenna (a) topview and sideview. (b) overall figure (c) picture of antenna

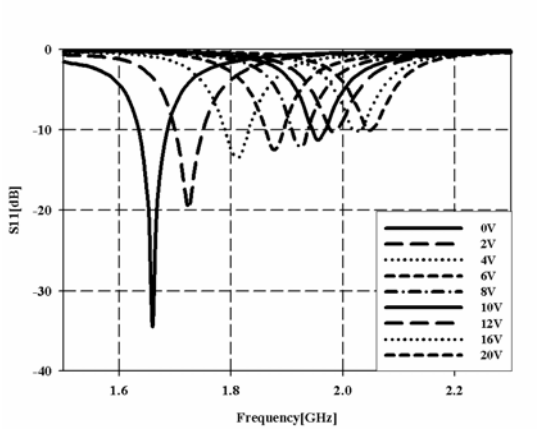
The configuration of the proposed antenna with varactor tuning method is illustrated in Fig. 1. An ABS material(εr =2.5) with the volume size of 40x13x6 mm^3 is inserted to support the DC bias feeding line of varactor diode between the antenna and FR4 substrate(εr = 4.6) with thickness of 1 mm and area size of (L, W) = (80, 45)mm, which is a typical size of handset PCB board. The height of this antenna(h) is 8 mm. The radiating element of the PIFA is grounded by a shorting pin at its left upper corner and fed by 50 ohm coaxial cable at the left side of antenna center line. One varactor diode is selected for the purpose of wide frequency tuning capability. The diode is attached between the inner radiating element at U-shaped slot and bias feeding strip line with folded L shape, as shown in Fig. 1(b). This folded L shape of antenna structure suppresses the first resonance frequency by the outer element of PIFA, but create another new resonance frequency which can cover several mobile communication bands. An inductor with a value of 82 nH is attached to the bias feeding strip line on the substrate for ac block, and this inductor as a role of RFC is connected to the DC biasing circuit by small thin wire. This antenna occupied a compact volume of 40 x 16 x 8 mm^3 which is enough small size to be included in mobile handsets.

3. Experiment and results

The antenna was fabricated by 0.2 mm thickness of copper plate mounted on the FR-4 substrate with a relative dielectric constant εr = 4.6. The overall ground size has 80 x 45 mm^2. The measured S_{11} results are performed by using Agilent 8510C Network Analyzer. The capacitance values of varactor diodes have varied starting from 0.2 pF to 1.15 pF with continuously associated the dc bias voltage ranging from 0V to 20V. Fig 2 shows the S_{11} characteristic of the simulated and measured results. The simulated results of antenna return loss were carried out CST Microwave Studio. The lower and higher resonant frequencies are operating at 1.64GHz and 2.05 GHz with changing the bias voltage from 0V to 20V, respectively. Total resonant frequency shifting can be achieved about 410 MHz operating frequency range, and the variation ratio is 22.16% at the center frequency of f_c = 1.85 GHz. Fig. 3 shows the E-H plane radiation patterns at the frequencies of 1.7 GHz, 1.8 GHz, 1.9 GHz and 2.0 GHz with corresponding dc bias voltage 0.4V, 3.1V, 6.1V and 11.2V. The proposed antenna has an almost omni-directional radiation pattern. The maximum antenna gains of the measured and simulated values have about 1.85 dBi and 1.9 dBi at the frequency of 1.8GHz, respectively. This slight discrepancy of the measure and simulated gains is attributing without considering the dc biasing circuit and battery and loss tangent of ABS material in the simulation. These electrical features of



(a)



(b)

Fig. 2. (a) Simulated S11 . (b) Measured S11

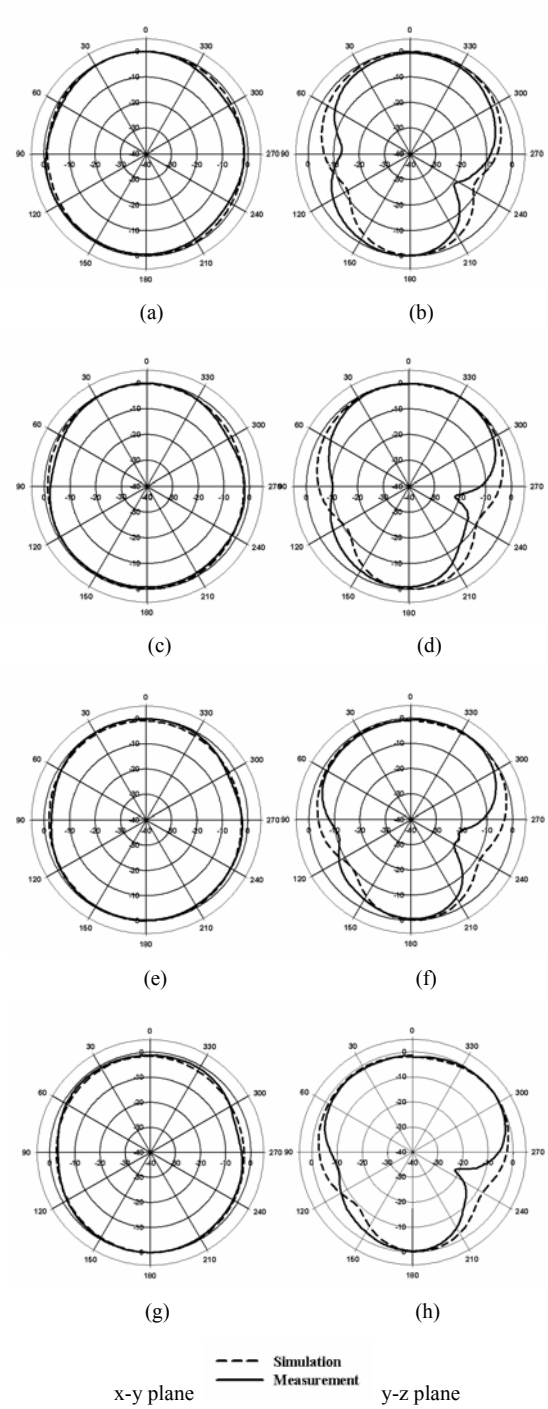


Fig. 3. Simulated and Measured radiation patterns

(a) E-plane of 1.7 GHz (b) H-plane of 1.7 GHz

(c) E-plane of 1.8 GHz (d) H-plane of 1.8 GHz

(e) E-plane of 1.9 GHz (f) H-plane of 1.9 GHz

(g)E-plane of 2.0 GHz (h) H-plane of 2.0 GHz

the proposed antenna are good characteristics for tunable antenna in mobile handset.

4. Summary

A novel PIFA type tunable antenna with U-shaped slot was fabricated and measured. By attaching a varactor diode between the U-shaped slot and the DC bias feeding strip line, the proposed antenna has achieving a wide frequency tuning range. In addition, this antenna has enough small size for mobile handsets. This new type of antenna may be considered for tunable antenna in 4-Generation mobile handset.

Acknowledgment

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