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A Capacitively Loaded Antenna for Use in Mobile Handsets

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Abstract— **A tuneable slotted patch antenna design is presented and verified for use in the DCS, PCS and UMTS bands. The tuning circuit consists of two varactor diodes, with some passive components, and is integrated fully with the radiator patch, with the varactors occupying different locations over the slot. The tuning does not require any further modification to the patch or feed geometry. Good agreement is observed between the predicted and observed impedance bandwidth, return loss, gain and radiation pattern, throughout the range 1.70 GHz – 2.05 GHz.**

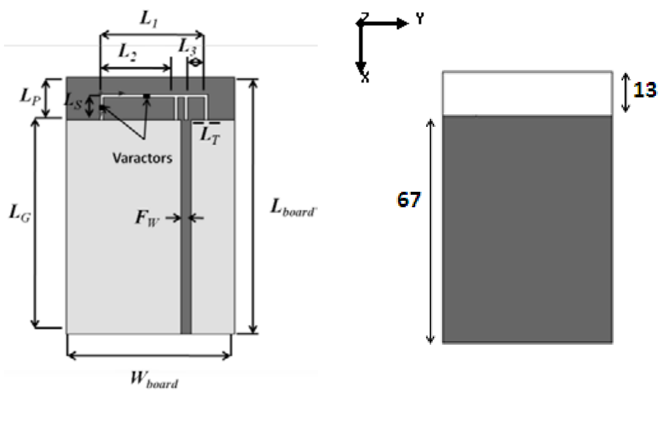
Keywords— **reconfigurable antennas, slot patch antennas, varactor diode.**

I. Introduction

The current emphasis on low profile space efficient antenna designs with suitable bandwidth for use in mobile multi-standard handsets and terminals continues to be a major design challenge. In addition to the usual wireless standards, antenna designers must also address possible wireless LAN and GPS requirements [1-2]. Microstrip patch radiators are a common starting point for such applications, but are fundamentally constrained in both bandwidth and gain. A further constraint imposed on patch antennas is the natural dimensioning imposed by the fundamental resonant modes. Size reductions may be achieved in several ways, e.g. the introduction of slots, or modified slotted geometries, such as the L-shaped, or split ring structures. Nevertheless, the resulting miniaturisation is not always sufficient for the lower frequency bands. Bandwidth can be improved through the introduction of lossy elements, but this has an impact on efficiency, alternatively one may look to tunable or re-configurable antennas [3-7], as well as dual and multi-band antennas [8]. Tuneable antennas offer several real advantages in terms of potential frequency agility, bandwidth expansion, and polarization diversity [9]. Varactor tuning is a well established technique in passive microwave sub-system design, these diodes are small, have a large capacitance ratio, and may be tuned through DC voltage control [10]. They offer one of the better solutions for an extension to the frequency range [11]. In the design exercise described below, two varactors are used to create a tuneable antenna with a fixed simple geometry, in which one varactor is used for adjustment, and a second provides the tuning correction. The target range should provide suitable coverage for DCS (1.71-1.88 GHz), PCS (1.85 GHz-1.99 GHz) and UMTS (1.90-2.20 GHz) services.

II. Antenna Design

The antenna is constructed on a rectangular sheet of FR4, the material has a DK of 4.4 and a loss tangent of approximately 0.02 over our frequency band. The PCB has a width of 50 mm (W_{board}), a length of 80 mm (L_{board}) and the substrate thickness is 1.6 mm, as shown in Fig. 1. The antenna is excited by a 5Ω microstrip feed line of width 3 mm (F_W). The optimised antenna dimensions are 13 mm (L_P) and length 50 mm, the metal etching is located on the top side of the substrate, and slotted, as shown, again in Fig. 1. The length of the ground plane is 67 mm (LG) with a 13 mm clearance below the antenna layout. Analysis and optimisation were carried out using Ansoft HFSS [12]. The selected slot dimensions were as follows: L_1 = 32 mm, L_2 = 7 mm, L_3 = 22 mm, and L_S = 7 mm, with a trace width (L_T) of 1 mm.



(a) (b)

Fig.1 Antenna structure (a) Top View (b) Bottom View, dimensions in mm.

III. Impact of Loading on The Antenna

The impact of the loaded varactor package (MMBV3102) on the antenna performance is assessed in terms of the return loss, radiation patterns and gains of the physical prototype. This is studied in comparison with a reference antenna structure, which does not incorporate a varactor. The unloaded reference antenna is only resonates at 1.4 GHz, as shown in Fig. 2; loading with two varactors act to shift the resonant frequency into the range 1.7 GHz to 2.05 GHz. The actual varactors, plus passive components, are shown with the antenna in Fig. 3. The tuning circuit consists of the diode package (MMBV3102), 100 nH inductors, and 100 Ω resistor. The variation of the RF-port return loss with the 'long-arm' and 'short-arm' varactor capacitance is given in Fig. 4. From these measurements, it can be seen that varying the 'long-arm' varactor DC bias from 0 V, through 5V, 9 V and 15 V, and keeping the 'short-arm' bias unchanged at 2 pF, the antenna may be tuned through the range 1.7 GHz to 2.05 GHz.

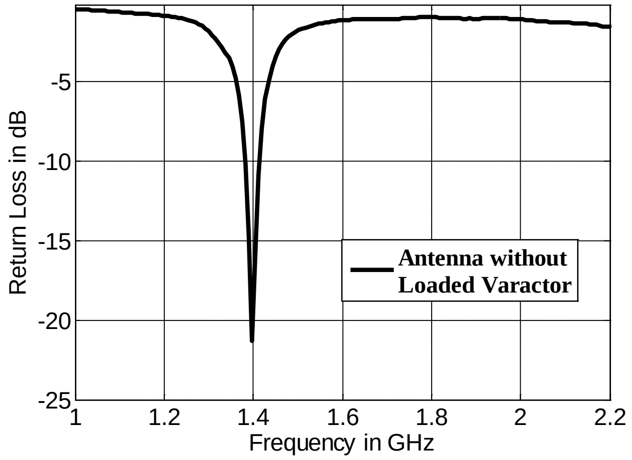


Fig. 2 Return loss of proposed antenna design without varactor loading

Fig. 3 Prototype antenna with DC bias circuit

IV. RESULTS

The tuning of the antenna relies on the introduction of the radiator arm slot on the radiator patch, which is derived from the HFSS model. The tuning is further assisted through the introduction of two varactor diodes attached at different locations over the slot, the capacitance of the first varactor is varied from 0.4 pF to 1.8 pF, and the second is held constant at 2 pF to achieve the desired tuning range. Simulated and measured return losses may be compared through Fig. 4, it can be seen that a single band antenna with a considerable tuning range may be obtained, with a return loss better than -10 dB.

The predicted (HFSS) and measured radiation patterns are given in Fig. 5, at 1.7GHz, 1.8 GHz, 1.9 GHz, and 2.05 GHz, with DC bias voltages of 0 V, 5V, 9 V and 15 V, respectively. These are plainly in close agreement with one another, again it may be inferred that uncertainty in the construction may account for the small variations. These radiation patterns are approximately omni-directional, and measurements were made in an anechoic chamber using a calibrated EMCO type 3115 broadband horn as the reference antenna. Two pattern cuts (H-plane and E-plane) were considered for a representative range of frequencies within the target bandwidth. The simulated patterns were generated from HFSS for the same cut planes.

Measured and simulated gains are reported in Fig. 6, the maximum gains achieved across our tuning range at the spot frequencies 1.7 GHz, 1.8 GHz, 1.9 GHz and 2.05 GHz were 2.9 dBi (3.4 dBi), 3.5 dBi (3.17 dBi), 2.38 dBi (2.51 dBi) and 1.55 dBi (2.42 dBi), respectively, the simulated figures are in parentheses. The variation between the predicted and measured gains may be due to inaccuracies in the fabricated prototype (i.e. dimensional tolerancing).

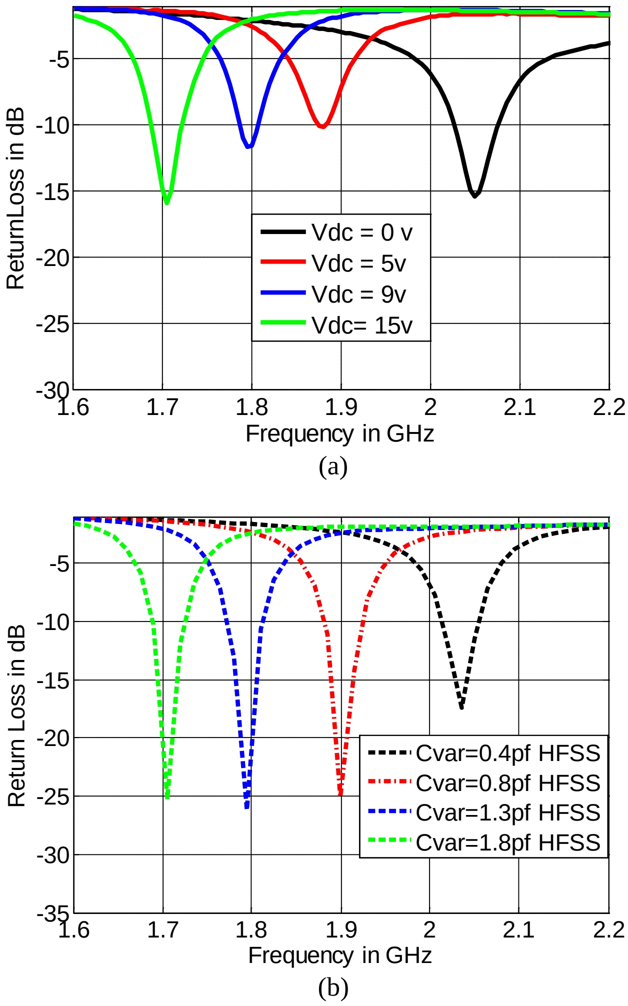


Fig.4 Input return loss at the input port; (a) Measured (b) HFSS Simluated

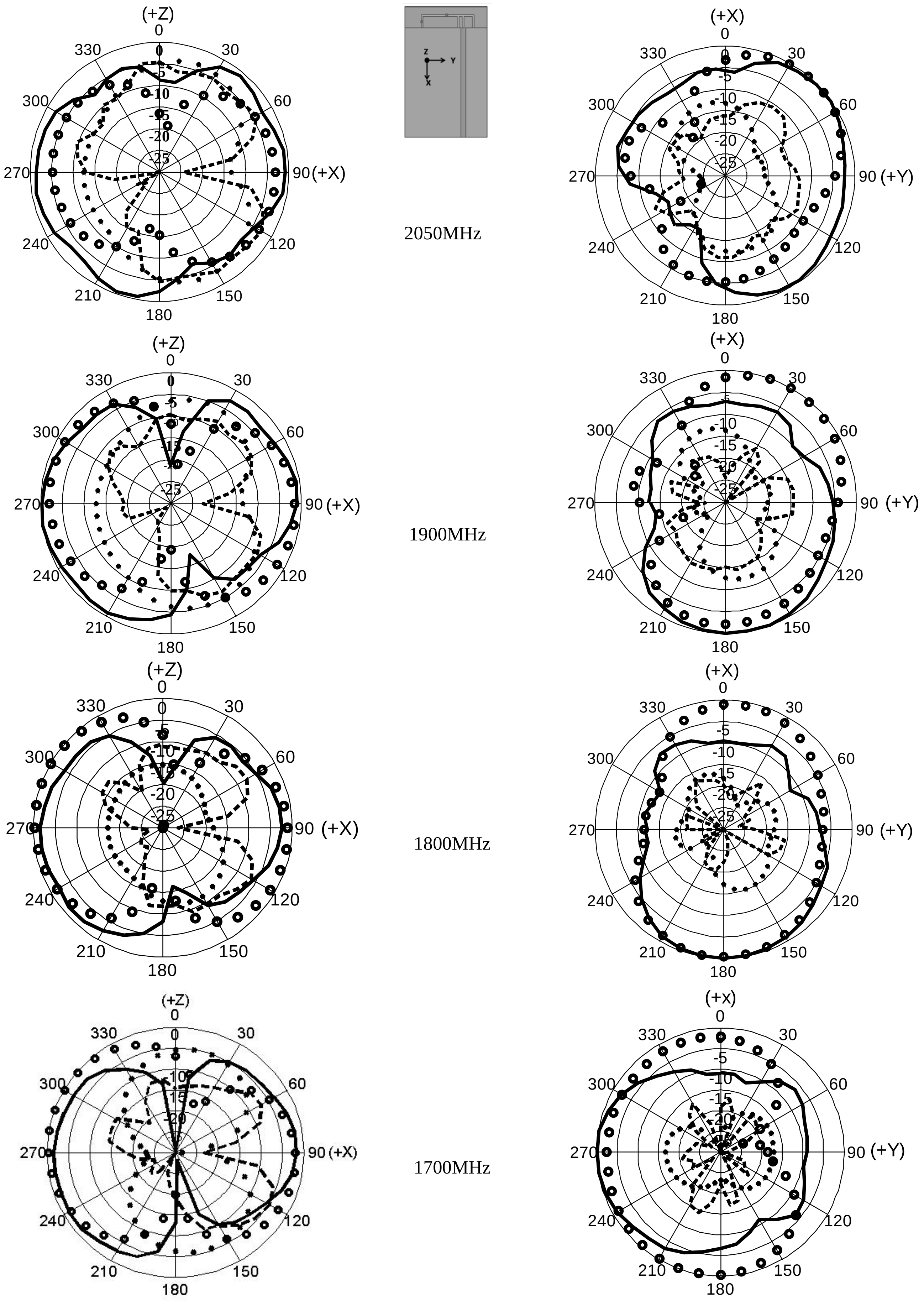


Fig.5 Simulated vs. Measured normalised antenna radiation patterns for two planes (left: xz, right: xy) at 1700MHz, 1800MHz, 1900MHz, 2050MHz.
'xxxx' simulated cross-polarization 'oooo' simulated co-polarization
'------' measured cross-polarization'——' measured co-polarization

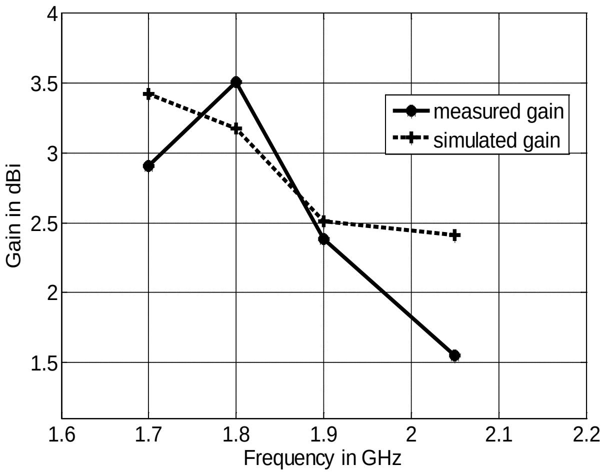


Fig.6 Measured and simulated gains of the proposed antenna

V. CONCLUSION

A capacitive loaded tuneable patch antenna, with a simple geometry, has been designed and constructed. The tuning technique uses two varactor diodes, the varactor loaded on the 'long-arm' is tuned through the range {0.4, 0.8, 1.3, 1.8} pF with a continuous DC bias voltage running over {0, 5, 9, 15} V. The antenna demonstrates an acceptable gain variation between 1.55 dBi and 3.5 dBi throughout the (frequency) tuning range. The predicted and measured results are in close agreement throughout for both polar and cross-polar field components.

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