C-shaped slot loaded reconfigurable microstrip antenna

S.V. Shynu, G. Augustin, C.K. Aanandan, P. Mohanan and K. Vasudevan

A new electronically reconfigurable dual frequency microstrip patch antenna with highly simplified varactor tuning circuitry is presented. The proposed design allows relatively independent selection of the two operating frequencies. Tuning ranges of 7.1 and 4.1% are realised for the two resonant frequencies without the use of any matching circuits.

Introduction: Compared to broadband antennas, reconfigurable microstrip antennas offer the advantages of compact size, frequency selectivity and similar radiation pattern and gain for all designed frequency bands [1]. Several interesting approaches to electronic tunability for different antenna structures have been carried out. However, the tuning mechanisms used are complex and need extra matching networks in order to operate over a wide frequency range [2]. Dual-frequency patch antennas may provide an alternative to large-bandwidth antennas. The key to providing a flexible solution is to have the radiators relatively independent [3, 4]. In this Letter, we present a novel, single-feed, dual frequency microstrip antenna design with independent frequency selection. Dual-frequency tuning has been realised using a varactor diode. The radiation pattern, gain and polarisation are essentially unaffected by the frequency tuning, which is highly desirable for frequency reconfigurable microstrip antennas.

Antenna design and configuration: Fig. 1 shows the configuration of the proposed reconfigurable dual frequency microstrip antenna. The antenna structure consists of a square microstrip patch with two embedded slots. The hexagonal slot is selected in an attempt to reduce the two orthogonal resonant modes to lower frequencies. Dual-frequency operation is achieved by perturbing the fundamental resonant mode of the patch with a 'C'-shaped slot, thus splitting it into two distinct orthogonal resonant modes (TM_{10} and TM_{01}). A method of moment based software (IE3D) is used to optimise the dimension and orientation of the slots in the square patch. The C-shaped slot extends to the current density regions of TM_{10} and TM_{01} modes. Independent control of two resonant frequencies is realised by varying either its vertical or horizontal dimensions and keeping the other unchanged.

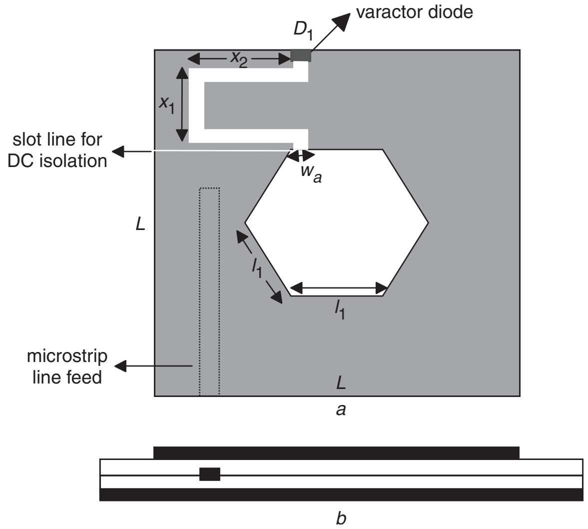

Fig. 1 *Schematic diagram of proposed reconfigurable microstrip antenna*

a Top view
b Side view
$L = 40$ mm, $l_1 = 8$ mm, $h = 1.6$ mm, $w_a = 1$ mm, $x_1 = 10$ mm, $x_2 = 16$ mm, $\varepsilon_r = 3.95$

Electromagnetic coupling with a 50 Ω microstrip line is used to feed the patch. The antenna is fabricated on a substrate of thickness 1.6 mm and $\varepsilon_r = 3.95$. The optimised square patch for dual-frequency L-band operation has dimension $L = 40$ mm, with a regular hexagonal slot of side dimension $l_1 = 8$ mm inserted at its centre. The C-shaped slot for dual-frequency generation and control is etched out with width $w_a = 1$ mm and lengths $x_1 = 10$ mm and $x_2 = 16$ mm, as shown in Fig. 1. Electronic tuning of both modes is accomplished by a varactor diode integrated across the slot. The junction capacitance of the varactor varies against the reverse bias applied and these different capacitive loadings correspond to different electrical lengths and thus different resonant frequencies. DC bias is applied across the varactor through two chip inductors. A narrow slot line is carved in the patch for DC isolation. Transmission lines are avoided in between the nonlinear components and radiating element, so that added noise and ohmic losses are suppressed and the resulting structure is more compact.

Experimental results: The fundamental resonant frequency of the unslotted square patch is 1.885 GHz. By etching the hexagonal slot at its centre it reduces to 1.74 GHz. With the C slot, two distinct resonant modes (TM_{10} and TM_{01}) at 1.472 and 1.752 GHz have been observed with a frequency ratio 1.19. Different C slot dimensions, x_1 and x_2, were tried to prove the independent frequency tuning capability of the proposed design. It was found that the first resonant frequency, f_1, can be tuned without affecting f_2, by varying x_1 and keeping x_2 unchanged. Similarly, the second resonant frequency, f_2 can be tuned by varying x_2 and keeping x_1 constant. The results are shown in Fig. 2.

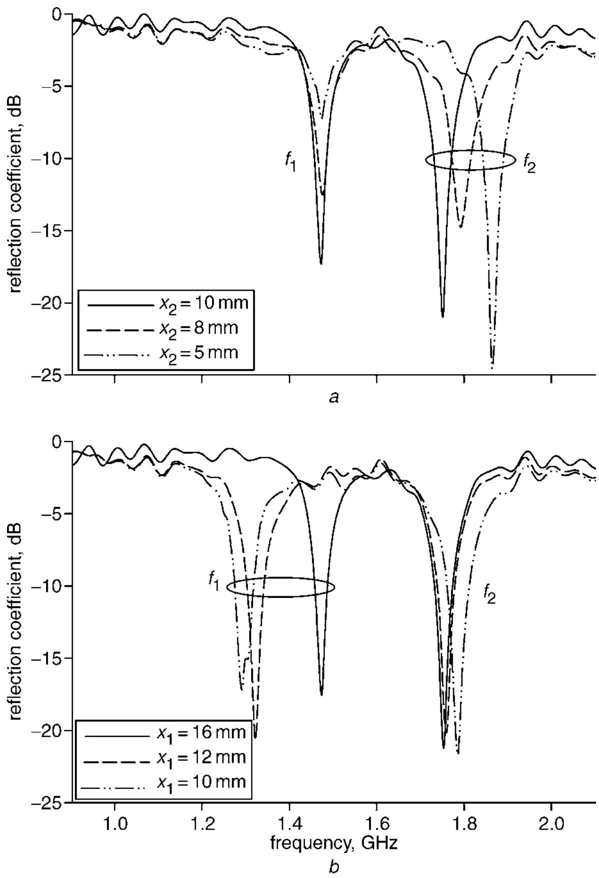

Fig. 2 *Variation of resonant frequencies with C slot dimension*

a $x_1 = 16$ mm and x_2 varying
b $x_2 = 10$ mm and x_1 varying

The antenna was then electronically tuned with a reverse DC voltage applied across the varactor. When the bias voltage is varied from 0 to −30 V, the tuning range for the first resonant frequency is found to be 7% or 104 MHz upwards (from 1.472 to 1.576 GHz) and that of second resonant frequency is 4% or 72 MHz upwards (from 1.752 to 1.824 GHz) as shown in Fig. 3. The gain of the antenna for specific x_1 and x_2 values remained almost constant in the entire tuning range. It is found to be approximately 2.25 and 1.04 dB less, respectively, for f_1 and f_2, compared to standard circular patches. Radiation pattern measurements of f_1 and f_2, at all bias levels, indicate that the patterns are unaffected by the electronic tuning. A typical radiation plot is given in Fig. 4. The design also offers a size reduction of 59 and 42% for f_1 and f_2, respectively, compared to standard rectangular patches. The polarisation planes of the two resonant frequencies are mutually orthogonal in the entire tuning range.

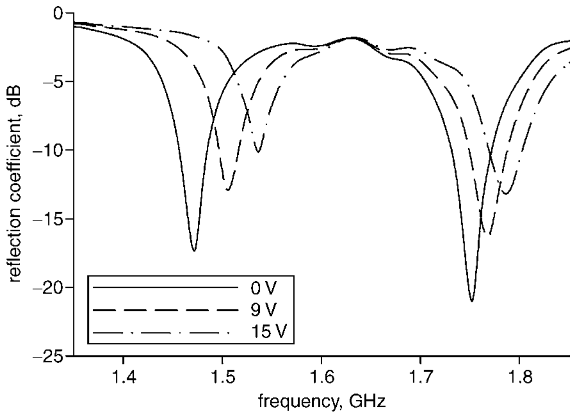

Fig. 3 *Return loss performance of reconfigurable antenna for $x_1 = 10$ mm and $x_2 = 16$ mm*

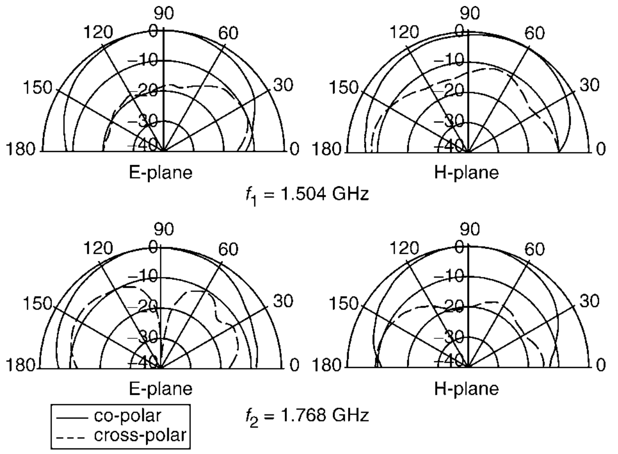

Fig. 4 *Radiation patterns of proposed antenna for $V = 9$ V, $x_1 = 10$ mm and $x_2 = 16$ mm*

Conclusions: We have presented a compact electronically reconfigurable dual-frequency microstrip antenna. Independent control of the two operating frequencies is possible with a C-shaped slot. The technique described uses a highly simplified varactor tuning circuit without any transmission lines.

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