Dual Band Reconfigurable Slot Antenna with High Frequency Ratio

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***Abstract*— In this paper, a design of compact dual band reconfigurable slot antenna is presented. The dual band operation is realised by effectively changing the slot electrical length using solid state shunt switches. Two resonant frequencies are obtained with the frequency ratio of 2:1. Although the ratio is high, good matching is achieved on both resonant frequencies without the need for a reconfigurable matching network. Also, radiation pattern, polarisation and efficiency remain reasonable similar at both frequencies. Computation results are confirmed with the experimental results.**

I. Introduction

Demands for reliable wireless communications are constantly on the rise. Emerging commercial applications often require low-cost compact antennas that must cover substantial bandwidth. However, having in mind tradeoffs associated with antenna size, bandwidth and efficiency [1], [2], constructing an antenna with aforementioned properties is a major challenge. In order to overcome these limitations, one can attempt a different approach by using the reconfigurable antenna concept [3]-[12]. Therefore, an alternative to a broadband antenna is a narrow band compact reconfigurable antenna with instantaneous bandwidths that are dynamically tuned at higher efficiency. Also, additional advantages are similar radiation pattern for all bands and frequency selectivity which reduces the need for additional filtering in the RF front end.

Electrical tuning of printed dipoles and slot antennas is reported in [7]-[12], since they both share attractive properties of low profile, portability and compatibility in integration with other monolithic microwave circuits (MMICs). A reconfigurable slot antenna was presented by Sarabandi *et al.* [10] where tuning ratio of 1.7:1 was achieved. No reconfigurable matching network was necessary and radiation properties were preserved at all resonant frequencies.

A slot antenna proposed in this paper is based on an outline presented in [10]. Shunt switches are employed to effectively change electrical length of the slot over a very wide frequency range. Two resonant frequencies are obtained and their ratio is nearly 2:1. Due to such high frequency ratio, a wideband matching is mandatory. Therefore, a radial stub is utilised to obtain a low return loss at both resonant frequencies. Radiation pattern is essentially the same at both frequencies. All measured results agree well with the computed ones.

II. Antenna Design and Operation

The geometry of the dual band reconfigurable antenna is depicted in Fig.1.

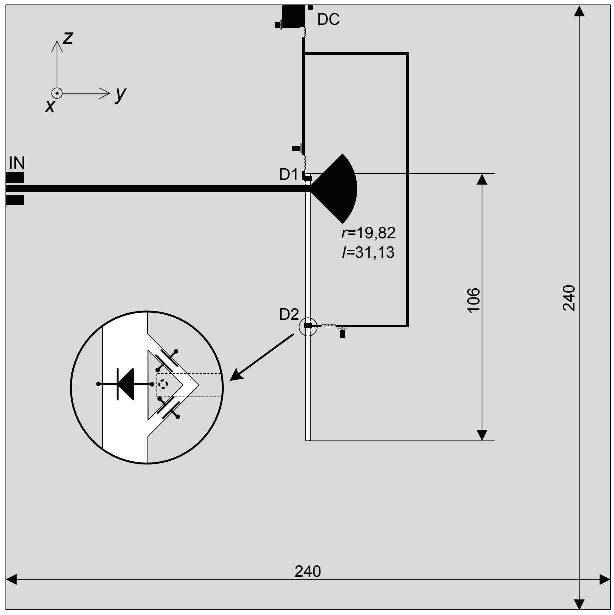

Fig.1 The antenna geometry

The antenna is fabricated on 1.51 mm thick FR-4 substrate (ε_r=4.3, tanδ=0.003) which theoretically enables 25 percent reduction of the radiating element size [10]. In the case of the fabricated antenna, the reduction is even greater, 30 percent. Slot is 2 mm wide and etched on the front (grey) side of the antenna while the 50 ohm feed line with the radial stub and the high impedance bias lines are etched on the back (black) side. The switches D_1 and D_2 are located 2 mm and 60.5 mm from the upper end of the slot, respectively. The feed line is 6 mm apart from the upper end.

Switches employed in this design are realised with the Agilent HSMP-3890 p-i-n diodes [13], [14]. The diode D_1 is used to improve matching and the diode D_2 has a role of changing effective slot length. At the lower resonant frequency both switches are in off-state, exhibiting high, capacitive impedance. The complete slot is

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electromagnetically active, resonating at 993 MHz. At the higher resonant frequency, both switches are in on-state, having a small inductive impedance. The operating frequency in this case is 1940 MHz. Since the ratio of the operating frequencies is nearly 2:1, an inductive coupling associated with the p-i-n diode D_2 would easily excite the part of the slot which should be inactive (beneath D_2). This would lead to substantial matching degradation and radiation pattern distortion. Therefore, both p-i-n diodes are compensated by accompanied capacitors which also serve as a part of the biasing circuit.

Due to the large difference between the operating frequencies, the matching could not be obtained good enough by using standard narrow band quarter wavelength stub. Therefore, a radial stub is utilised.

Figs 2 and 3 are showing photographs of the dual band antenna.

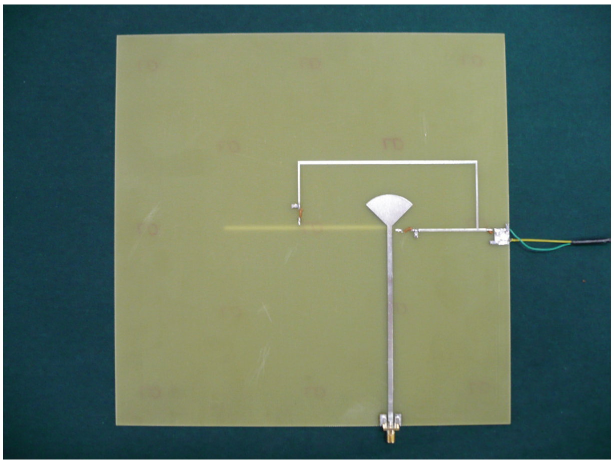

Fig. 2 The back side of the antenna

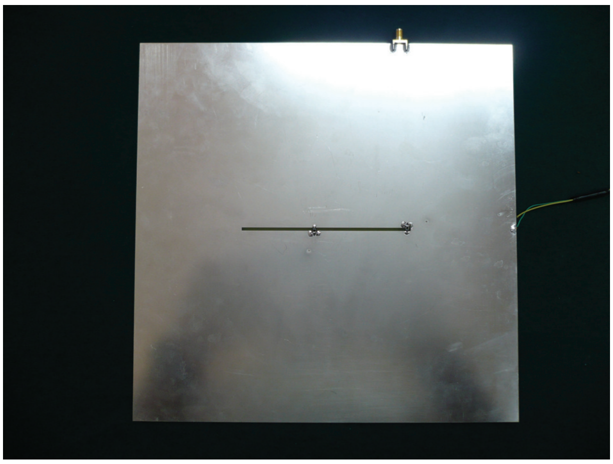

Fig. 3 The front side of the antenna

III. Measurement Results and Discussion

A. Return Loss Results

Simulation and measurements results are shown on Figs 4 and 5.

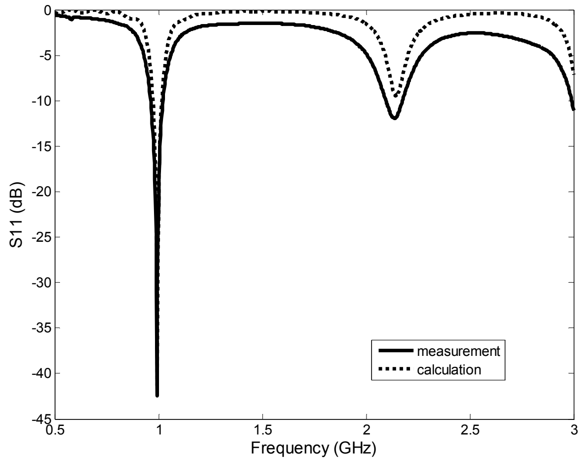

Fig. 4 Measured and calculated results for the return loss, diodes in the off state

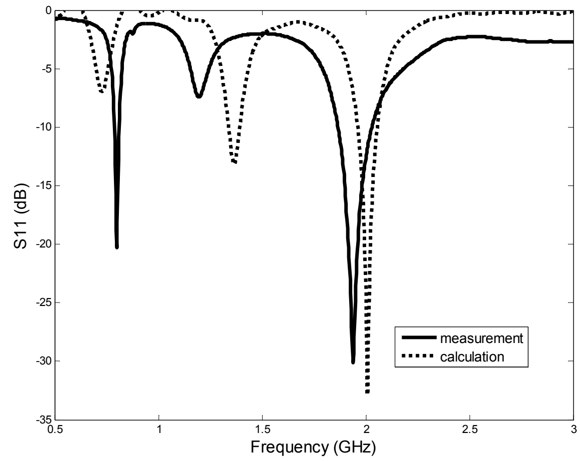

Fig. 5 Measured and calculated results for the return loss, diodes in the on state

In both cases the discrepancy between measurement and calculation is very small. Calculations are obtained using CST Microwave Studio software package [15], while the measurements are performed using Rohde&Schwarz ZVA40 Vector Network Analyser. The measured impedance bandwidth (VSWR<2) at the lower frequency is approximately 60 MHz (6.04 percent) while at the higher resonance is 164 MHz (8.45 percent).

B. Radiation Patterns

Figs 6-13 are showing measured and calculated radiation patterns.

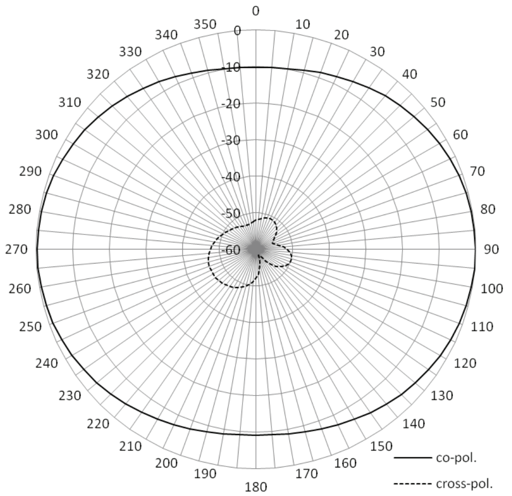

Fig. 6 The calculated radiation pattern, *H*-plane (*xz*), 993 MHz

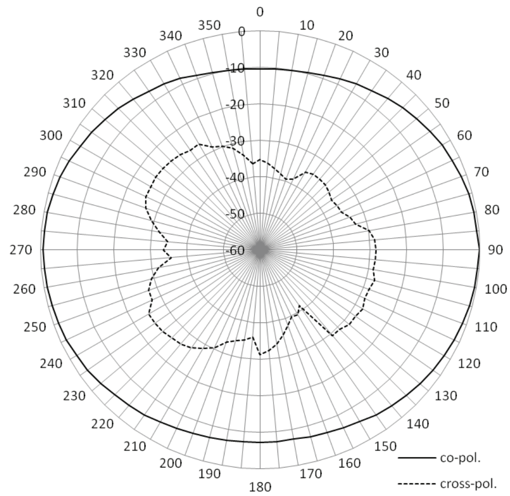

Fig. 7 The measured radiation pattern, *H*-plane (*xz*), 993 MHz

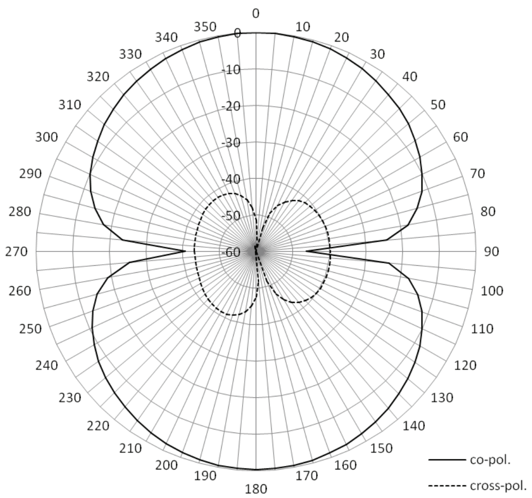

Fig. 8 The calculated radiation pattern, *E*-plane (*xy*), 993 MHz

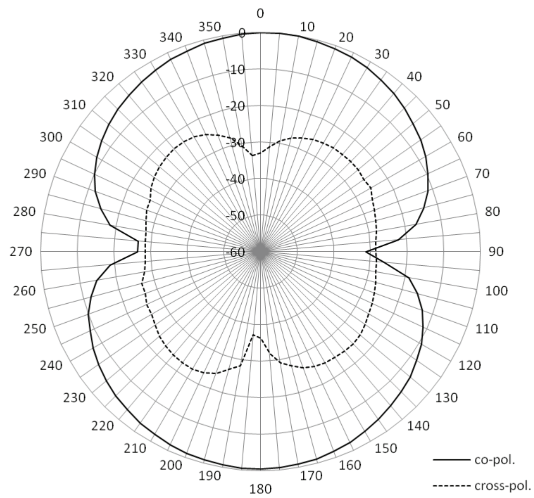

Fig. 9 The measured radiation pattern, *E*-plane (*xy*), 993 MHz

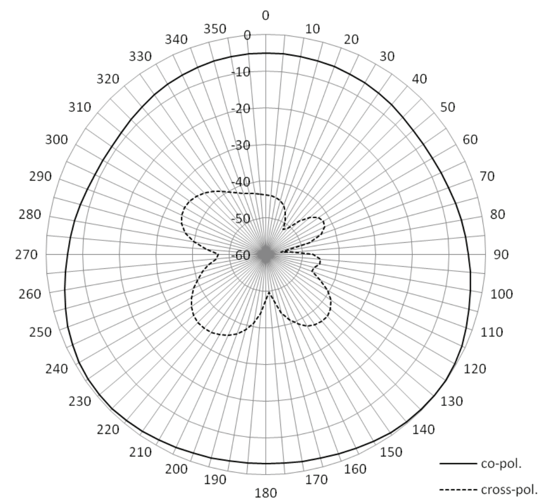

Fig. 10 The calculated radiation pattern, *H*-plane (*xz*), 1940 MHz

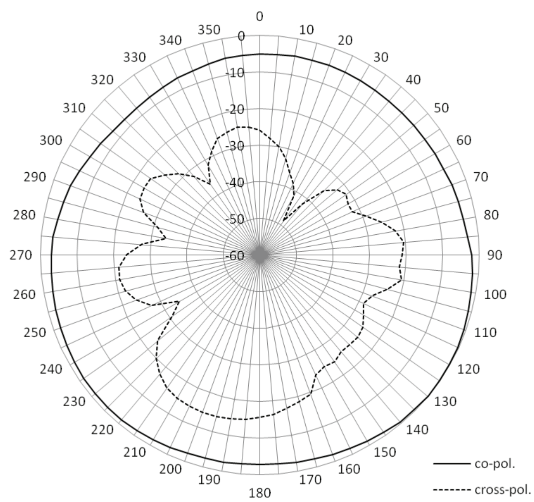

Fig. 11 The measured radiation pattern, *H*-plane (*xz*), 1940 MHz

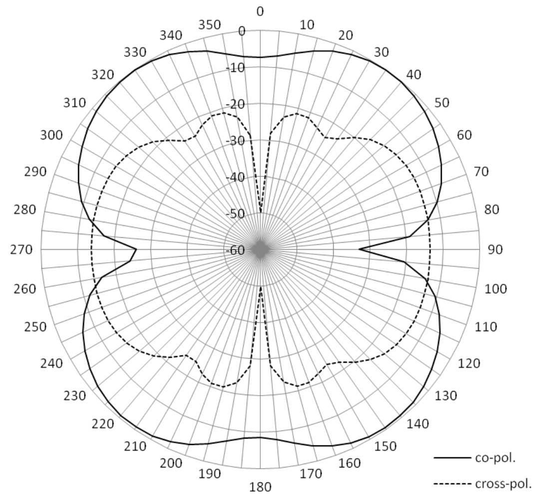

Fig. 12 The calculated radiation pattern, *E*-plane (*xy*), 1940 MHz

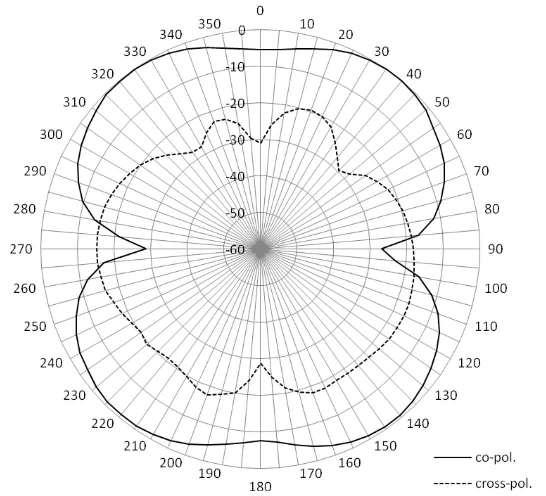

Fig. 13 The measured radiation pattern, *E*-plane (*xy*), 1940 MHz

Radiation pattern calculations and measurements are obtained using aforementioned software package and instrumentation. Co-polarisation measurement results show an excellent agreement with the calculated data. Cross-polarisation measurement results are also correlated with calculations. However, due to the unavoidable reflections in the measurement setup, the measured cross-polar shows substantially greater levels in comparison with the calculations.

Radiation pattern variations caused by the frequency tuning are minor and can be neglected for many possible applications.

The measured gain data of the antenna is approximately 1 dB below the predicted values at both resonant frequencies.

IV. Conclusions

A compact, single feed, cost effective electronically tuneable dual band slot antenna is presented in this paper. Important issues considering design, such as wideband matching and diode impedance compensation are discussed. The antenna is constructed, fabricated and analysed. High frequency ratio of 1.95:1 is obtained. A significant size reduction is achieved using FR-4 substrate. The antenna exhibits very low return loss and radiation patterns remain unaffected by the frequency tuning. A good agreement between the simulations and experimental results is observed.

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