Dual Frequency Reconfigurable Microstrip Antenna using Varactor Diodes

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Abstract

A varactor controlled electronically reconfigurable dual frequency microstrip antenna is presented. Dual frequency operation is realized by embedding an X-slot in a rectangular patch. High tuning ranges of 26.3% and 15.3% are realized for the two resonant frequencies respectively, when the bias voltage is varied from 0 to 16V. This design has an added advantage of size reduction up to 77% and 64% for the two resonant frequencies compared to standard rectangular patch. A maximum band width of 2.26% and 2.36% for the two frequencies with an operating frequency ratio varying in the range 1.156 to 1.279 is observed.

1. Introduction

Reconfigurable antennas have recently received much attention for their applications in wireless communications, electronic surveillance and countermeasures, by adapting their properties to achieve selectivity in frequency, bandwidth, polarization and gain. Frequency agile systems must be able to receive signals over a wide frequency range and therefore, requires either wide-band or tunable antennas. Instead of wide-band antennas, tunable narrow-band antennas provide frequency selectivity which relaxes the requirement of receiver filters. Also, reconfigurable microstrip antennas offer the advantages of compact size, frequency selectivity and similar radiation pattern and gain for all designed frequency bands. Slot antennas are common for frequency tuning because their resonant frequency can be changed easily with varactors or switches [1-3].

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 [4]. 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 [5-6]. In this paper, we present a single-feed dual frequency reconfigurable microstrip antenna capable of achieving high tuning ranges without using any matching networks. The tuning of the two resonant frequencies is realized by varying the effective electrical length of the slot arms by embedding varactor diodes across the slots. The radiation pattern, gain and polarization are essentially unaffected by the frequency tuning, which is highly desirable for frequency reconfigurable microstrip antennas.

2. Antenna geometry

The geometry of the proposed antenna is shown in Fig. 1. The antenna is fabricated on a substrate of thickness h (1.6 mm) and relative permittivity ε_r (4.4). The initial cross patch is obtained by removing the four square regions of side L_s mm from the corners of a rectangular patch of size L x W mm^2. An X-slot of arm length L_x mm and width W_x mm is then carved at the center of the cross patch. The antenna is electromagnetically coupled using a 50Ω microstrip line fabricated using the same substrate material. The dimension of the ground plane is 75 x 75 mm^2. Varactor diodes D_1, D_2, $D_3$and D_4 are positioned at the extreme end of the slot arms in order to get maximum tuning range and better matching. DC bias voltage is supplied from a battery through chip inductors.

3. Results and Discussion

The fundamental resonant modes (TM_{10} and TM_{01}) of the unslotted cross shaped patch are at 1.67GHz and 2.19GHz with orthogonal polarizations. The proper selection of the slot size modifies the horizontal and vertical

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electrical lengths of the patch equally so that the two resonant frequencies are lowered to 1.12GHz and 1.44GHz. The reflection characteristics of the antenna with and without X-slot are given in Fig.2. The antenna exhibits good radiation characteristics for both resonant frequencies with an area reduction of 77% and 64% for the first and second frequency respectively when compared to a standard rectangular patch operating at the same frequencies.

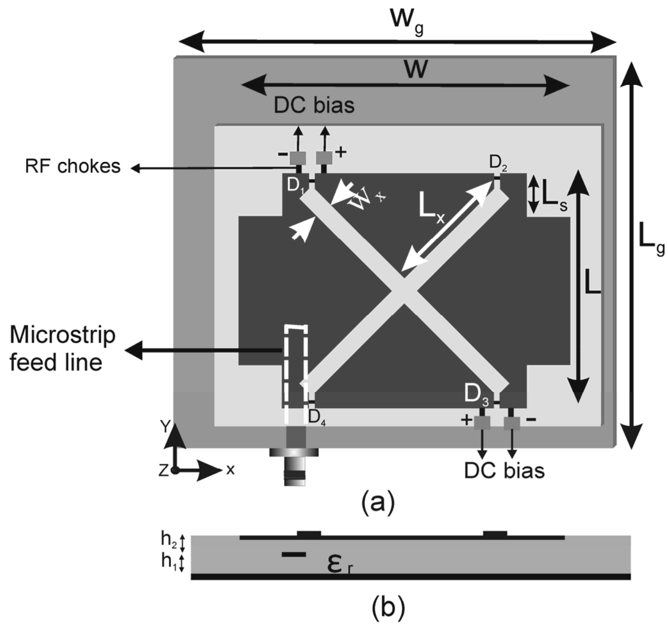

Fig. 1. Geometry of the proposed antenna (L= 30.9, W= 43.5, L_s= 5.1, L_x= 17.6, W_x= 2.3, h_1= h_2= 1.6, L_g=W_g=75(All lengths are in mm) and ε_r= 4.4) (a) Front view (b) side view.

To attain an insight on the effect of slot geometry on the antenna performance, the proposed antenna is designed for different slot sizes. The X-slot length (L_x) modifies the first and second resonant modes equally while slight variations in resonant frequencies are observed when the width (W_x) is varied but this change is found to be negligible compared to that of slot length. The change in the resonant frequencies with slot length is shown in Fig 3. To implement electronic reconfigurability, varactor diodes are directly integrated across the extended slot arms and DC bias is applied through two chip inductors. The junction capacitance of the varactors varies against the reverse bias voltage applied and these different capacitive loadings correspond to different electrical lengths and thus different resonant frequencies. The positions of the varactors are so selected to achieve maximum frequency tuning while less perturbing the antenna matching.

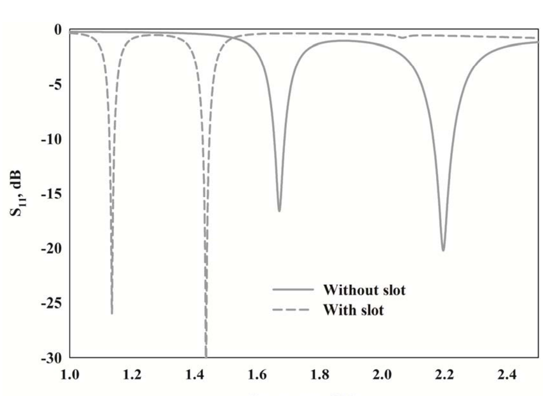

Fig.2 Reflection coefficient of the cross patch antenna with and without X-slot

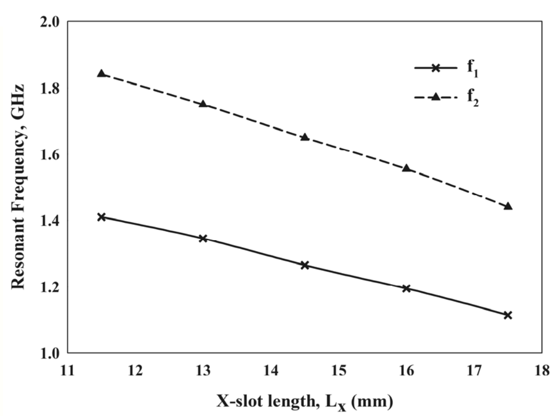

Fig.3 The response of first and second resonance modes with X-slot length

The antenna is tested using HP8510C Network Analyzer and the measured reflection coefficients of the antenna for different bias voltages are shown in Fig.4. When the reverse bias is OFF, the varactor loadings in all the slot arms correspond to high capacitance. Thus the resonant frequencies are lowered to 1.03 GHz and 1.28GHz with a frequency ratio of 1.279. The reconfigurable antenna was then electronically tuned with a reverse DC voltage applied across the diodes. When the bias voltage is varied from 0 to 16 V, the tuning range for the first resonant frequency is found to be 26.3% or 279MHz upwards (from 1.02 to 1.299 GHz) and that of second resonant frequency is 15.3% or 197MHz upwards (from 1.305 to 1.502 GHz). At 16V the frequency ratio is found to be 1.156. The variation of first and second resonant frequencies (f_1 and f_2) with the applied varactor reverse bias voltage is measured and plotted in Figure 5. Fig. 6 shows the simulated surface current distribution of the antenna at 1.03GHz and 1.28GHz. It is observed that the X-slot modifies the electrical lengths of TM_{01} and TM_{10} modes of the patch which result an orthogonally polarized dual frequency reconfigurable antenna.

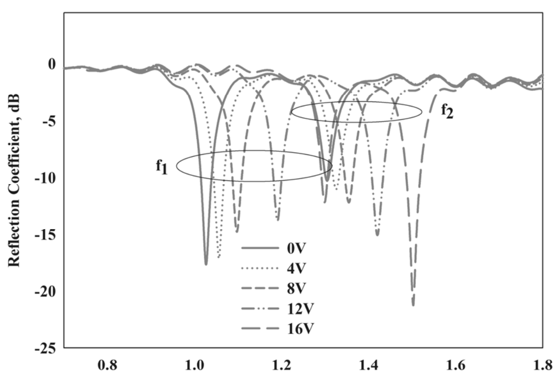

Fig.4 Measured Reflection characteristics of the antenna for different bias voltages

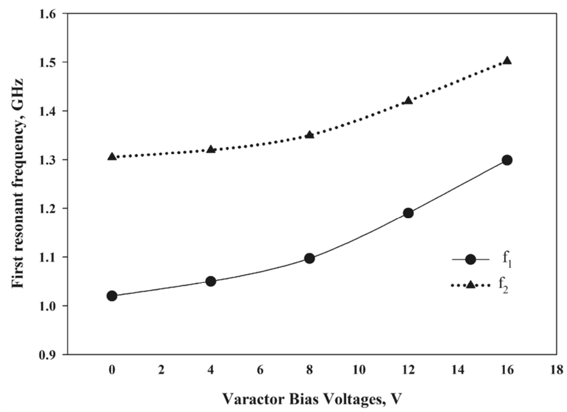

Fig.5 Variation of resonant frequencies against reverse bias voltages (a) f_1 and (b) f_2

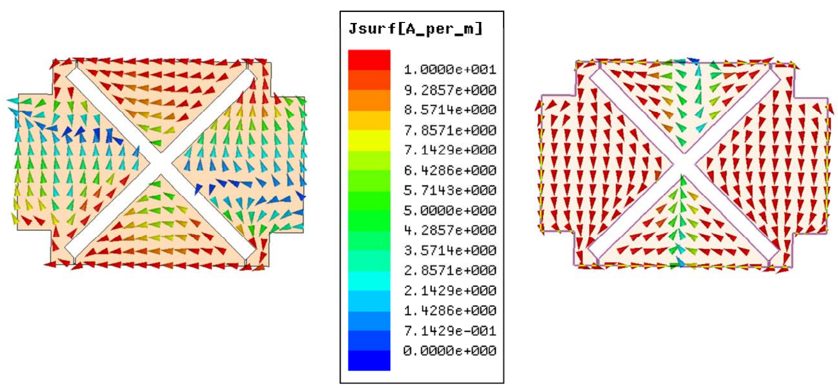

Fig.6 Simulated surface current distribution of the antenna at (a) 1.03GHz and (b) 1.28GHz

The *E* and *H*-plane radiation patterns of the reconfigurable antenna are measured for different bias voltages. All the patterns show similar broadside radiation characteristics with good cross polarization levels even when the operating frequencies are shifted greatly by applying reverse bias. Typical radiation patterns for the resonant frequencies of 1.03GHz and 1.28Hz for 0V and 1.3GHz and 1.48GHz for 16V are given in Fig.7(a), (b), (c) and (d) respectively. Bandwidths up to 2.26% and 2.36% respectively, have been obtained in the two modes. The polarization planes of the two resonant frequencies are mutually orthogonal in the entire tuning range. The peak gain of the reconfigurable antenna is found to be nearly 2.1 dB and 1.2 dB less for the first and second resonant frequencies respectively. The low gain values are due to the opposing currents on either side of the slot arm which cause field cancellation along the axis at the far-field.

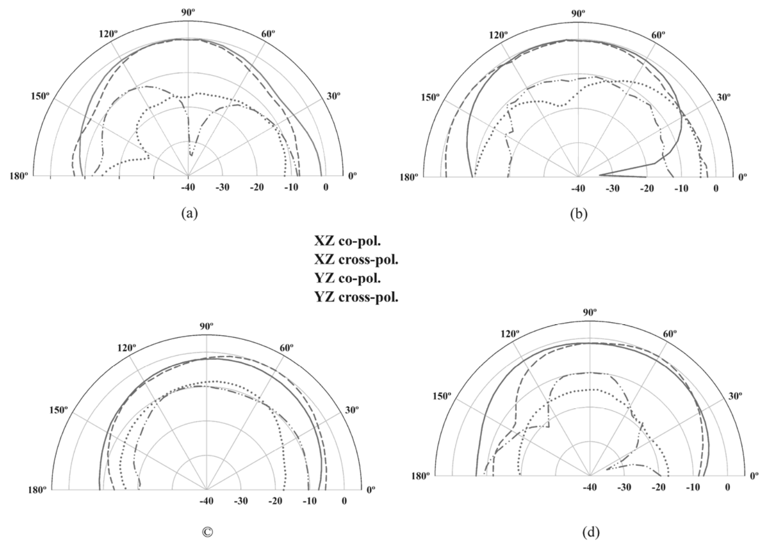

Fig. 7 Measured radiation patterns at (a) 1.03GHz (b) 1.28GHz (c) 1.3GHz and (d) 1.48GHz

4. Conclusion

A single feed design of compact, electronically reconfigurable dual frequency microstrip antennas is proposed. The concept is based on the electronic tuning of embedded slots in the patch antenna using varactor diodes. A high tuning range of 26.3% (1.02–1.299 GHz) and 15.3% (1.305–1.502 GHz) is achieved for the two operating frequencies respectively, when the bias voltage is varied from 0 to 16V. The salient feature of this design is that it uses no matching networks even though the resonant frequencies are tuned in a wide range with good matching below −10 dB. The antenna has an added advantage of size reduction up to 77% and 64% for the two operating frequencies compared to conventional rectangular patches. Another feature of this antenna is that the radiation characteristic is remaining essentially unaffected by the frequency tuning.

5. Acknowledgment

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6. References

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