SIR based Frequency Reconfigurable Antenna using Varactor Diodes

Manoj M, Remsha M, Shameena V A, Anila P V and P. Mohanan
Department of Electronics, Cochin university of Science and Technology, Kochi, India

Abstract

A varactor controlled electronically reconfigurable dipole antenna is presented. The property of a stepped impedance resonator is utilized to achieve the resonant frequency of the dipole antenna. By embedding varactor diodes on the dipole arms and varying the reverse bias voltage, the current flow distribution in the radiating structure can be changed. Experimental results shows that by trimming the varactor diode, a high tuning range of 780 MHz (1.98 GHz-2.76 GHz) is achieved.

1 Introduction

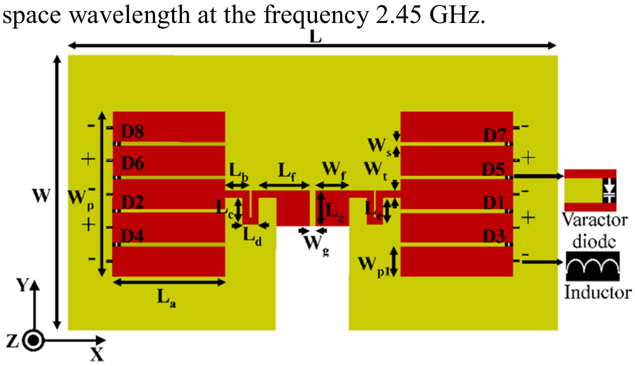
Frequency reconfigurable antennas are useful for modern wireless communication because a single antenna can cover several application bands. The attractive features such as reconfigurable capability, multipurpose function, low cost and miniaturized size have given the frequency reconfigurable antennas much attention in wireless communication [1-4]. By increasing the electrical length of the antenna or the current route on the antenna, the resonance frequency can be reconfigured [5], [6]. Frequency of operation of the reconfigurable antennas are electronically tuned over a bandwidth by tuning an embedded microelectromechanical systems (MEMS) or varactor diodes. Another possibility is to incorporate switching positive intrinsic negative (PIN) diodes to change the effective electrical length of the radiator [7]. Microstrip slot antennas are common for frequency reconfigurability because their resonant frequency can be easily tuned with varactor or PIN diodes. However the tuning mechanism used are complex and need an additional substrate for feeding the antenna [8], [9]. The air gap between the substrate and ground plane is utilized to lower the effective permittivity of the antenna. For the proper tuning of the antenna resonant frequency, the thickness of the air gap should be trimmed.

In this paper, we present a stepped impedance dipole antenna capable of achieving high tuning ranges without using any matching networks or additional substrates. The tuning of the antenna resonant frequency is realized by varying the effective electrical length of the dipole arms by embedding varactor diodes at the gap between the consecutive metallic strips of the dipole arms. The proposed dipole antenna has advantages such as low cost, compact size, easy to fabricate, simple integration and omnidirectional radiation pattern.

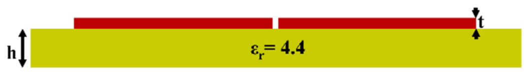
The antenna characteristics are measured using an Agilent PNA E8362B and all the far field measurements are performed inside the anechoic chamber.

2 Antenna Geometry

The geometry of the proposed dipole antenna is shown in Figure 1. The antenna is fabricated on a substrate of thickness h= 1.6 mm, relative permittivity $\varepsilon_r = 4.4$ and tan $\delta = 0.02$. The dipole antenna has an overall dimension of $0.408\ \lambda_0 \times 0.245\ \lambda_0 \times 0.013\ \lambda_0$, where λ_0 represents the free-space wavelength at the frequency 2.45 GHz.



(a)



(b)

Figure 1. Geometry of the proposed dipole antenna (L= 0.408 λ_0, W = 0.245 λ_0, L_a= 0.081 λ_0, W_g= 0.00408 λ_0, L_b= 0.0163 λ_0, Wp= 0.12 λ_0, Lc= Le= 0.0179 λ_0 , W_{p1}= 0.022 λ_0, L_d= 0.00163 λ_0,W_s = 0.00245 λ_0, L_f= 0.0408 λ_0, W_t = 0.0049 λ_0, L_g= W_f = 0.0245 λ_0, h =0.013 λ_0 , ε_r= 4.4 and tan δ = 0.02) (a) Top view (b) Side view

The electrical length of the dipole arm is formed by La and L_t= L_b+ L_c+ L_d + L_e + L_f. The L_t is folded as in Figure 1 to reduce the overall size of the antenna. Each arm of the dipole antenna have two stepped impedances Z_1= 100 Ω and Z_2= 15 Ω are calculated from the widths W_t and W_p respectively. As per stepped impedance resonator theory, the impedance ratio is given by K= Z_1/Z_2, and the length ratio is given by α= L_a/ (L_t + L_a). The K and α values for the proposed dipole antenna at 2.45 GHz are 0.15 and 0.43 respectively. Varactor diode D1 to D8 are positioned at the extreme end of the dipole arms in order to get maximum tuning range and better impedance matching. DC bias voltage is supplied from variable power supply (0- 30V) through chip inductors.

3 Results and Discussions

The simulated and measured reflection coefficients of the antenna without activating varactor diodes are shown in Figure 2. It is observed that the antenna is resonating at 2.45 GHz with 17.14 % bandwidth from 2.24 GHz to 2.66 GHz. The reflection coefficient value at the resonance is found to be 30dB.

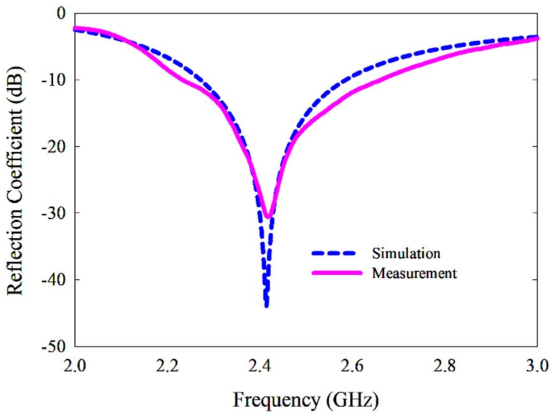


Figure 2. Reflection coefficient of the proposed dipole antenna without activating varactor diodes.

The variation of resonant frequency in different cases of switching with the applied reverse bias voltage is measured and plotted in Figure 3. In the first case of switching, varactor diodes D1 and D2 are enabled and the remaining diodes are disabled. The dipole antenna was then electronically tuned with a reverse DC voltage applied across the diodes. When the bias voltage is varied from 0 to 25 V, the tuning range of the resonant frequency is found to be 21.22 % or 520 MHz upwards (from 2.24 to 2.76 GHz) and is depicted in Figure3.

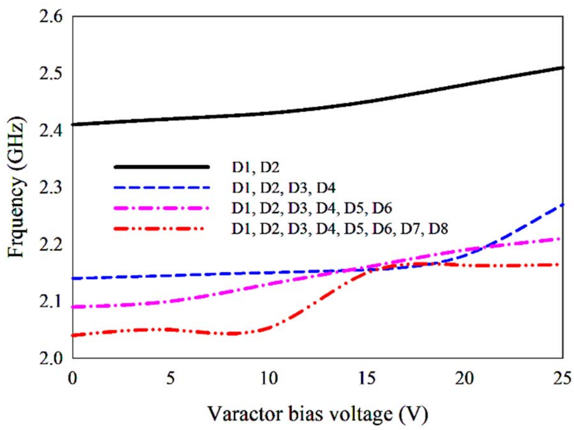


Figure 3. Measured variation of resonant frequency against different reverse bias voltages.

In the second case, the diodes D3 and D4 also enabled, hence the reconfigurability is achieved with two varactor diode in each arm. In this case the obtained tuning range of resonance is 17.67 %, from 2.04 to 2.42 GHz. Similarly, the diodes D5 and D6 are also enabled in the third case. In this case the measured resonance frequency variation is from 2.05 to 2.31 GHz and is shown in Figure 3. All four pair of varactor diodes are from D1- D8 are activated in the fourth case of switching. In this case, the tuning range starts from 1.98 to 2.26 GHz and this frequency variation is also plotted in figure 3.

All the numerical simulations and optimizations were performed using electromagnetic simulation tool CST microwave studio and the simulated reflection coefficients of the antenna for different frequency switching cases are shown in Figure 4 (a) - Figure 4 (d).

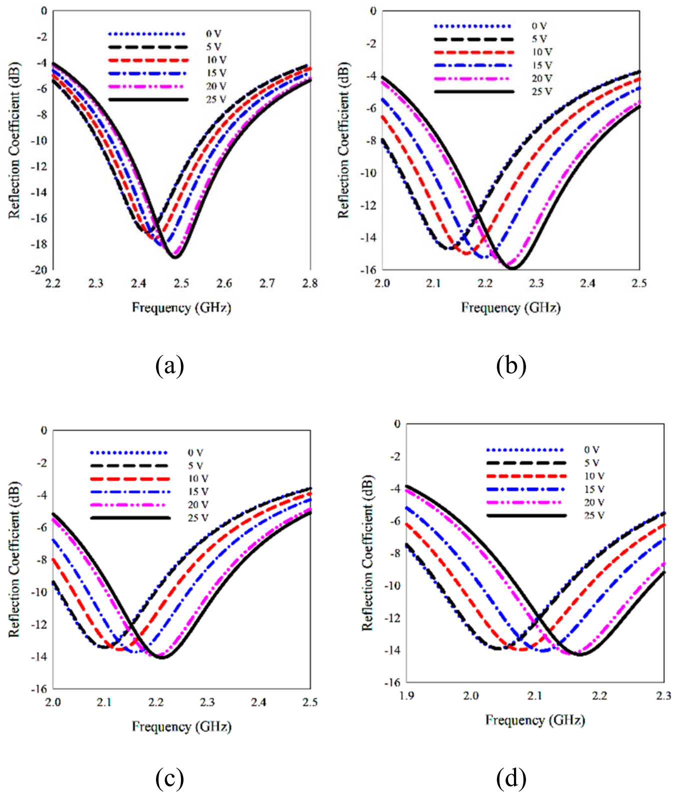


Figure 4. Simulation results of frequency switching (a) Enabling D1 and D2 (b) Activating D1-D4 (c) Enabling D1-D6 (d) Activating D1-D8.

The simulated and measured omnidirectional radiation pattern of the antenna at the application band 2.45 GHz are plotted in Figure 5. The antenna shows the normalized cross polarization levels are below -20 dB in both E and H planes. This shows that the embedded varactor diodes have a small impact on the cross polar levels of the antenna.

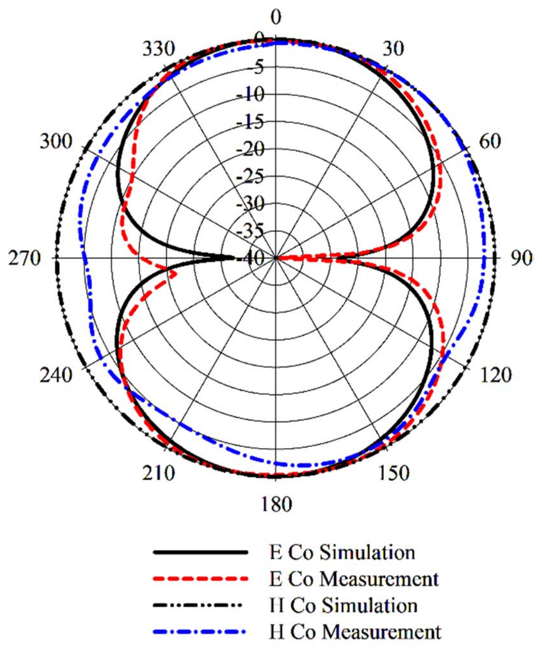


Figure 5. Normalized omnidirectional radiation pattern of the antenna at 2.45 GHz.

4 Conclusion

A stepped impedance based frequency reconfigurable antenna for WLAN (2.4- 2.48 GHz)/ bluetooth (2.4-2.48 GHz)/ LTE (2.4-2.7 GHz)/ WiMAX (2.5-2.7 GHz) has been presented in this paper. The concept is based on the electronic tuning of dipole arm using varactor diode. The simulation and experiments are well matched and offer a 2:1 VSWR (S11< -10 dB) bandwidth of 780 MHz. The salient features of this design is that, it does not require matching networks or additional substrate to feed the antenna. Another feature of this antenna is that the radiation characteristic is omni directional.

5 Acknowledgements

The authors acknowledge the University Grants Commission of Government of India and the Department of Science and Technology (DST) for financial assistance.

6 References

1. A. Mirkamali and P. S. Hall, "Wideband frequency reconfiguration of a printed log periodic dipole array," Microw. Opt. Technol. Lett., vol. 52, no. 4, pp. 861–864, Apr. 2010.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

2. Y. Tawk and C. G. Christodoulou, "A new reconfigurable antenna design for cognitive radio," IEEE Antennas Wireless Propag. Lett., vol.8, pp. 1378–1381, 2009

3. Y. Yu, J. Xiong, H. Li, and S. He, "An electrically small frequency reconfigurable antenna with a wide tuning range," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 103–106, 2011.

4. Y. Zhang, B. Z. Wang, and X. S. Yang, "Fractal Hilbertmicrostrip antennas with reconfigurable radiation patterns," Microw. Opt. Technol. Lett., vol. 49, no. 2, pp. 352–354, Feb. 2007.

5. H. Li, J. Xiong, Y. Yu, and S. He, "A simple compact reconfigurable slot antenna with a very wide tuning range," IEEE Trans. Antennas Propag., vol. 58, no. 11, pp. 3725–3728, Nov. 2010.

6. M. Komulainen, M. Berg, H. Jantunen, E. T. Salonen, and C. Free, "A frequency tuningmethod for a planar inverted-F antenna," IEEE Trans. Antennas Propag., vol. 56, no. 4, pp. 944–950, Apr. 2008.

7. J. L. A. Quijano and G. Vecchi, "Optimization of an innovative type of compact frequency-reconfigurable antenna," IEEE Trans. Antennas Propag., vol. 57, no. 1, pp. 9–18, Jan. 2009.

8. D. Peroulis, K Sarabandi and Linda P B Katehi, "Design of reconfigurable slot antennas", IEEE Trans. Antennas Propag., vol.53, No.2, 645-653, 2005.

9. M. S. Nishamol, V. P. Sarin, D. Tony, C. K. Aanandan, P. Mohanan, and K. Vasudevan, "An Electronically Reconfigurable Microstrip Antenna With Switchable Slots for Polarization Diversity", IEEE Trans. Antennas Propag., vol.59, No.9, 3424-3427, 2011.