PERFORMANCE EVALUATION AND ANALYSIS OF FREQUENCY RECONFIGURABLE DIELECTRIC RESONATOR ANTENNA

KM NEHA VERMA[1], Dr. RISHI ASTHANA[2]

[1]M.Tech, Electronic and Communication Engineering, GITM, Lucknow, India
[2]Professor, Department of Electrical Engineering, GITM, Lucknow, India

***

Abstract - *In this line of investigation, the initial step is to develop a basic dielectric resonator antenna that has microstrip strips attached to two of the edges of the dielectric resonator. The value of rr = 10 is used to represent the dielectric constant of the DR, which has dimensions of 13 mm 13 mm 10 mm. The DR is positioned on a ground plane with dimensions of 100 millimetres by 150 millimetres and a substrate with a rr value of 3.38. There are six distinct working conditions that may be accomplished by placing shorting tabs along one edge of the DRA. Second, a frequency reconfigurable DRA in the form of a H that uses coplanar waveguide (CPW) feed is given here. This antenna is made up of two different types of dielectric resonators, each of which has a dielectric constant of 15. On a substrate with a dielectric constant of 3.2, the DRs are positioned. In order to activate the DRA, the CPW feeding approach is used. On the line that connects the dielectric resonators, there are two PIN diodes installed for usage. By using these PIN diodes, it is possible to acquire three different working modes, such as off on, off on, and on on. In the OFF ON state, two bands are obtained, one with a centre frequency of 2.7 GHz for the WLAN application and the other with a centre frequency of 4.8 GHz for the INSAT (Indian national satellite system) use. When the switch is in the ON-OFF position, a single narrow band with a centre frequency of 3.7 GHz is produced for use in wireless local area network (WLAN) and international mobile telecommunications (IMT) applications. In a manner analogous, when the ON ON state is selected, a dual band consisting of the frequencies 2.6917 and 5.2589 is produced for use in WLAN applications.*

Key Words: reconfigurable dielectric resonator antennas, frequency analysis, dielectric constant, Finite Element Method, substrate material, resonance frequency, microstrip patch antenna, rectangular dielectric resonator antenna, return loss, radiation pattern.

1. INTRODUCTION

Reconfigurable dielectric resonator antennas (RDRAs) are a type of antenna that can be tuned to different frequencies by adjusting their physical properties. RDRAs are composed of a dielectric resonator, which is a piece of material with a high dielectric constant, and a conducting element, such as a microstrip patch, that is used to excite the resonator. By changing the dielectric constant of the resonator, the resonant frequency of the antenna can be adjusted. RDRAs have been shown to have superior performance compared to other types of antennas, particularly in terms of their radiation pattern and return loss. They are used in a variety of applications, including wireless communication, radar systems, and satellite communication systems.

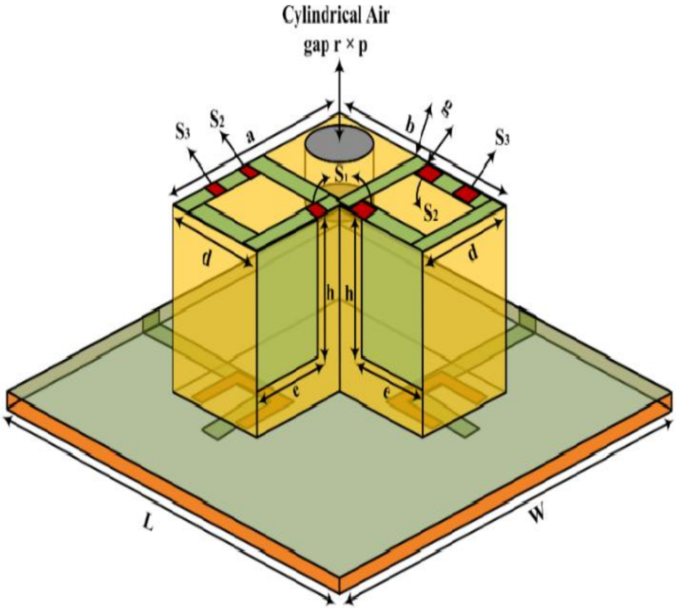


Figure-1: Reconfigurable dielectric resonator antennas

The principle of reconfigurable dielectric resonator antennas (RDRAs) is based on the ability of dielectric materials to affect the resonant frequency of the antenna. When a high dielectric constant material is placed near a conductive structure, it creates a resonant structure with a specific resonant frequency. By changing the dielectric constant of the material, the resonant frequency of the structure can be adjusted.

RDRAs consist of a dielectric resonator and a conducting element, such as a microstrip patch or a slot. The dielectric resonator is a piece of high dielectric constant material that is excited by the conducting element. By changing the dielectric constant of the resonator, the resonant frequency of the antenna can be tuned.

There are several methods for changing the dielectric constant of the resonator in RDRAs, including the use of varactor diodes or micro-electromechanical systems (MEMS) switches. Varactor diodes are used to change the capacitance of the resonator, which in turn changes the resonant frequency. MEMS switches are used to change the shape of the resonator, which also affects the resonant frequency.

Overall, the principle of RDRAs is to create a resonant structure that can be tuned to different frequencies by adjusting the dielectric constant of the material. This allows for a highly versatile and adaptable antenna that can be used in a wide range of applications.

The purpose of reconfigurable dielectric resonator antennas (RDRAs) is to provide a flexible and adaptable solution for wireless communication systems, radar systems, and satellite communication systems.

RDRAs offer several advantages over traditional fixed-frequency antennas, including the ability to tune to multiple frequencies without the need for physically changing the antenna structure. This flexibility allows for a single antenna to be used for multiple applications, reducing the need for multiple antennas and simplifying the design and installation process.

1.1. Factor Affecting Reconfigurable Dielectric Resonator Antennas

There are several factors that can affect the performance of reconfigurable dielectric resonator antennas (RDRAs), including:

1. Dielectric Constant: The dielectric constant of the material used in the resonator affects the frequency at which it resonates. By changing the dielectric constant of the material, the resonant frequency of the antenna can be tuned.

2. Resonator Geometry: The size and shape of the resonator can also affect the resonant frequency of the antenna. Changing the geometry of the resonator can change the resonant frequency of the antenna.

3. Substrate Thickness: The thickness of the substrate used in the antenna can affect its radiation pattern and impedance bandwidth.

4. Feeding Technique: The way in which the antenna is fed can also affect its performance. Different feeding techniques can be used to achieve different radiation patterns and impedance bandwidths.

5. Reconfiguration Mechanism: The mechanism used to reconfigure the antenna can also affect its performance. For example, some RDRAs use MEMS switches to reconfigure the antenna, while others use varactors or other types of tunable components.

6. Operating Environment: The operating environment, including factors such as temperature, humidity, and electromagnetic interference, can also affect the performance of RDRAs.

1.2. Limitation of DRAs

One limitation of DRAs is their narrow bandwidth. The resonant frequency of the DRA is highly dependent on the dielectric constant of the material used in the resonator. This can lead to a narrow bandwidth that may not be sufficient for some applications. Various techniques, such as multiple resonator structures and the use of metamaterials, can be used to broaden the bandwidth of the DRA.

Another limitation is the difficulty in achieving polarization diversity. DRAs are typically designed to radiate in a single polarization, which limits their ability to receive or transmit signals with different polarizations. Various techniques, such as stacked DRAs and multiport feeding, can be used to achieve polarization diversity, but these techniques can increase the complexity and cost of the antenna.

A further limitation is their sensitivity to surrounding objects. The radiation pattern and resonant frequency of the DRA can be affected by nearby objects, such as conductive surfaces and other antennas. This can lead to a reduction in the antenna's performance and may require careful placement and shielding.

Finally, the use of high-permittivity dielectric materials can limit the operating temperature range of the DRA. At high temperatures, the dielectric material can experience thermal degradation, which can lead to a change in the resonant frequency and a reduction in the antenna's performance.

Overall, while DRAs have many advantages, their limitations must be carefully considered in the design and implementation of practical antenna systems.

2. PROBLEM STATEMENT

The problem at hand is the lack of comprehensive analysis and understanding of the design, performance, and optimization of frequency reconfigurable dielectric resonator antennas. Existing research in this field primarily focuses on individual aspects of FR-DRAs, such as reconfigurable materials, tuning mechanisms, or specific frequency bands. However, a systematic investigation that encompasses the overall design considerations, operational characteristics, performance limitations, and optimization techniques for FR-DRAs is lacking.

Moreover, the design of FR-DRAs is inherently complex, involving a multitude of parameters and trade-offs. The selection of suitable reconfigurable materials, the integration of tuning mechanisms, and the determination of optimal control strategies require in-depth analysis and evaluation.

The impact of these design choices on antenna performance metrics, such as radiation pattern, gain, bandwidth, and efficiency, needs to be thoroughly investigated to develop practical guidelines and design methodologies for FR-DRAs.

3. RESULT AND ANALYSIS

First, microstrip strips are affixed to the perimeter of a simple dielectric resonator antenna. The DR measures 13mm x 13mm x 10mm and has a rr = 10 dielectric constant. The DR is mounted on a 100 mm x 150 mm substrate with rr = 3.38. To switch between the DRA's six modes, just short the tabs along one edge. The second kind is a DRA that is supplied by a coplanar waveguide (CPW) and has a variable operating frequency. This antenna consists of two dielectric resonators, each having a dielectric constant of 15. The DRs are supported by a substrate with a dielectric constant of 3.2. The CPW feeding method helps to raise the DRA. To connect the dielectric resonators, two PIN diodes are used in a wire. These PIN diodes have three possible operating states: off-on, on-off, and on-on. When the switch is in the ON position, it acquires a 2.7 GHz band for wireless local area network (WLAN) usage and a 4.8 GHz band for use with INSAT (India's national satellite system). A single, narrow band at 3.7 GHz, usable for WLAN and IMT, is created by toggling between a "ON" and "OFF" setting. Similarly, in the ON ON state, a dual band with frequencies of 2.6917 and 5.2589 is formed for WLAN applications.

4. FIRST DESIGN OF FREQUENCY RECONFIGURABLE DIELECTRIC RESONATOR ANTENNA

First design employs edge-grounded dielectric resonator antenna. Figure 5 shows edge-gronded DRA. One edge rests. This shorting wall aligns electric and magnetic fields normal and tangential to the conductor, as shown. Walls shorten resonance frequency. Shorting the wall decreases the resonance frequency from 5 GHz to 3.5 GHz in the recommended configuration.

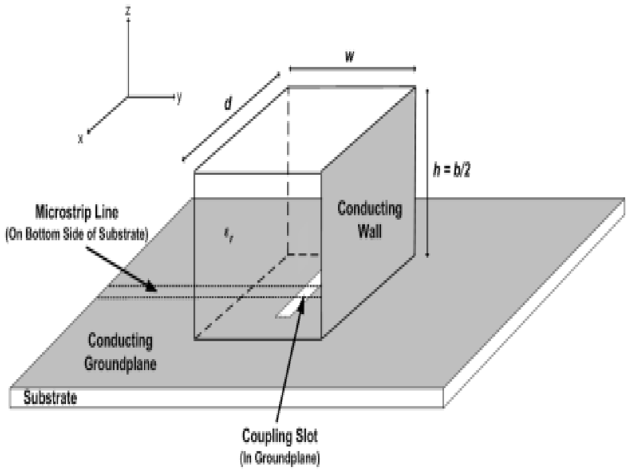


Figure-2: Rectangular DRA with ground edge.

4.1. Simulation Result of First Proposed Antenna

The only component that is thrilled to start with is the DRA because, when employing the configuration that was just explained, which results in a frequency of 4.945 GHz and a return loss value of -22.59 dB, the DRA is the only component that is excited. The final result is equivalent and has a return loss of -26.59 when two microstrip strips are added to each side of the DRA. The incorporation of the microstrips brings about this result. Doing this step is essential in order to bring the circuit to a successful conclusion.

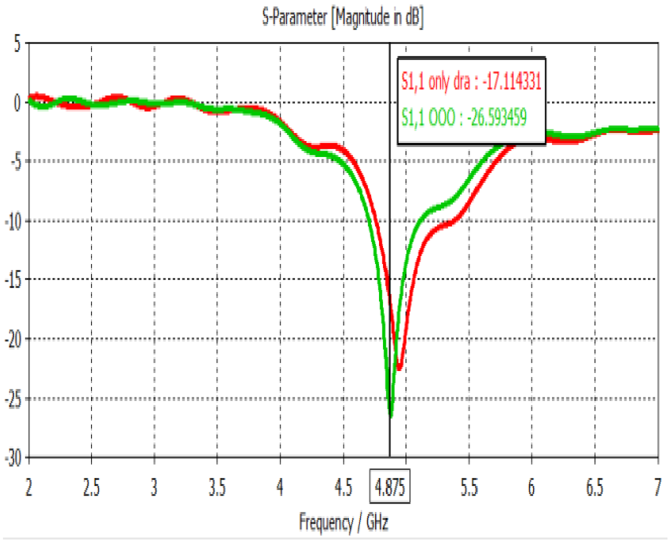


Figure-3: Return loss curves of just DRA and DRA with two microstrip strips.

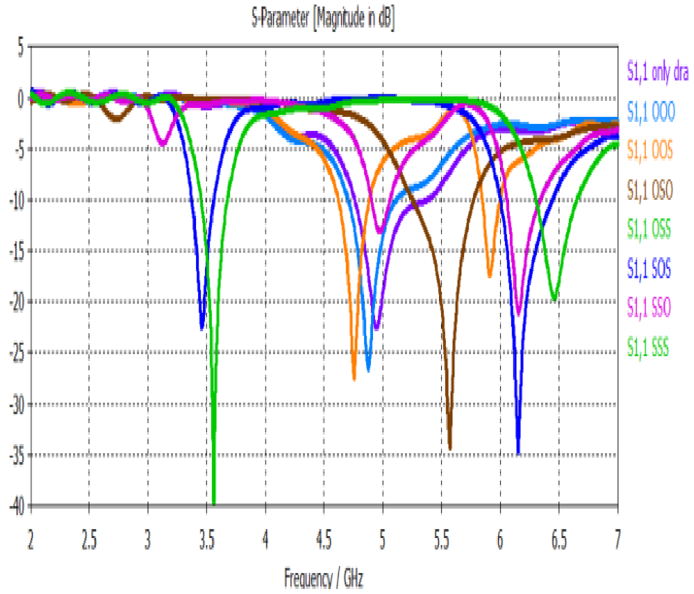
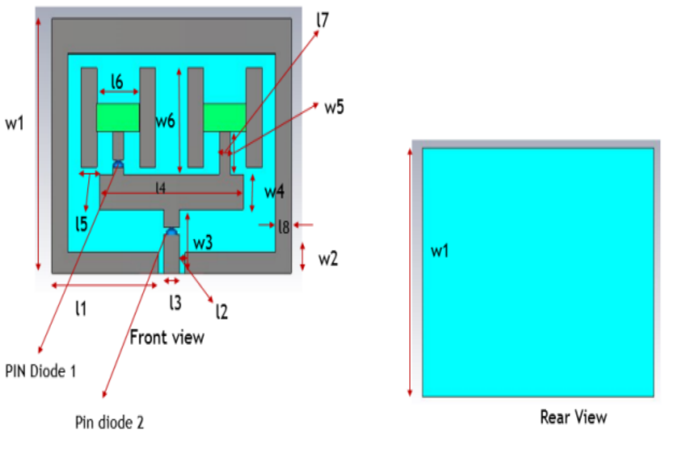


Figure-4: Antenna return loss plot at 6 circumstances.

5. SECOND DESIGN OF COPLANAR WAVEGUIDE-FED H-SHAPED FREQUENCY RECONFIGURABLE DRA

5.1. The Proposed Antenna's Geometry

Dielectric resonators flank both sides of the aerial. The DRA is increased with the help of the CPW feeding approach. The DRA is protected on both sides by microstrip holes. A Taconic substrate, with a dielectric constant of 3.2 and a thickness of 1.6, is positioned underneath the feed line.



(a) (b)

Figure-5: Front and back views of the planned aerial.

5.2. Three-Way Loss-Return Curve for Various Modes of Operation

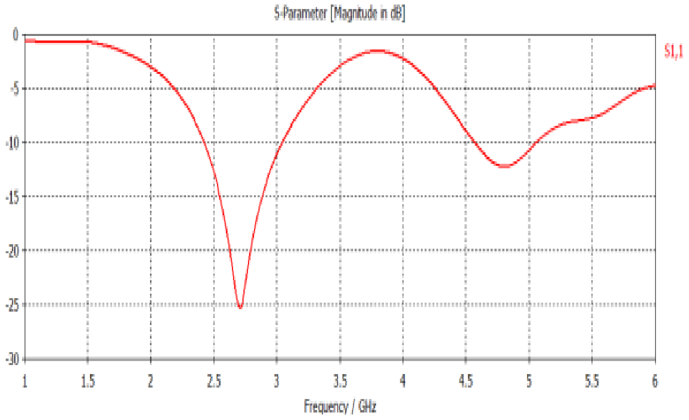


Figure-6: Return loss versus. Frequency in OFF-ON state.

The snapshot that was supplied to you had the only purpose of illustrating the difference between the OFF and ON positions in order to make the procedure more understandable for you. This results in the acquisition of two bands, each of which has a distinct centre frequency: 2.7 GHz for use with WLAN, and 4.8 GHz accordingly, for use with INSAT. Both of these bands may be used to communicate using radio waves (the Indian national satellite system).

6. THIRD DESIGN

6.1. Geometry for Suggested Antenna.

This design employs two dielectric resonators with different diameters but the same dielectric constant (10). Dielectric resonators over 0.05-mm ground planes. Aperture coupling feeding excites DRAs. Ground plane aperture slots below the DRA activate two dielectric resonators. Feed-from-below. Power divider concept excites DRAs simultaneously. Feed networks link DRAs to inputs. 50 quarter wavelength converters at each feed network end recreate a 50-ohm line divided into 100. Dielectric resonators receive power equally.

Switchless aerial testing. 2.9GHz WLAN. The first DRA is 20 mm x 20.3 mm x 6.7 mm and the second is 14 mm x 8 mm x 8.10.

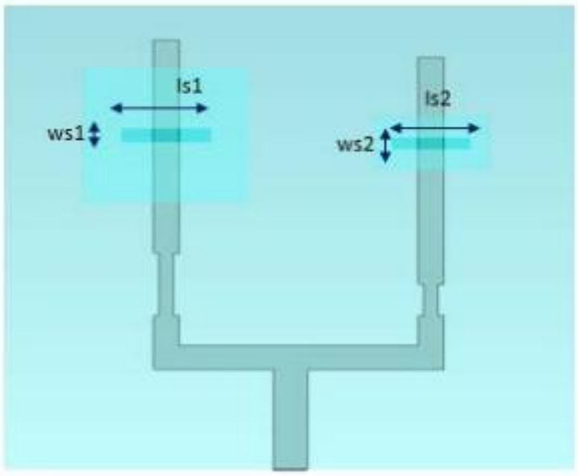


Figure-7: Front, rear, and aperture slot views of the planned aerial.

6.2. Simulation results

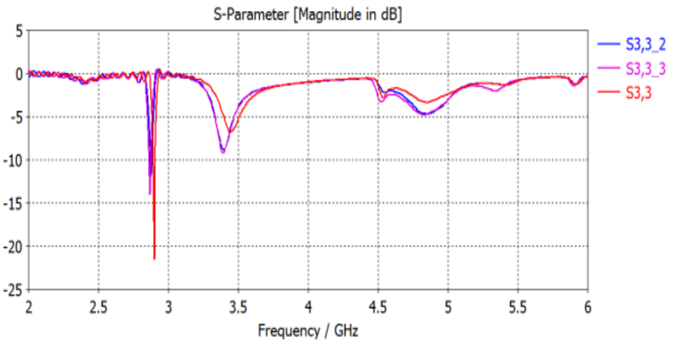


Figure-8: plot of Return loss/frequency.

WLAN applications utilise 2.9 GHz. 4% antenna impedance bandwidth and -22 dB return loss.

7. CONCLUSION

Here, we introduce and investigate three novel frequency-configurable dielectric resonator antennas for use in wireless communications. Wireless local area networks (WLANs) operating at 2.7-3.1 GHz and 5.1-6 GHz, wireless metropolitan area networks (WIMAXs) operating at 3.3-3.7 GHz, the International Mobile Telecommunications System (IMTS), the Indian National Satellite System (INSAT) at 4.5-4.8 GHz, and so on could all make use of these antennas. The basic antenna consists of a DRA edge shorted to the ground plane. You may quickly switch between the six available options by using one of three tabs. Here, the shorting tabs serve admirably as switches. With CST studio suite 2012, all of the settings have been fine-tuned. The simulation results indicate several methods of deploying the aerial. The second and third antennas are re-configurable due to the use of PIN diodes and have dual dielectric resonators. PIN diodes have several desirable properties, thus their potential applications are being researched. They have several advantages, such as being cheap, quick to switch, and easily accessible. The CPW feeding method requires the ground plane for the second antenna to be mounted vertically above the substrate. The completed schematic shows the antenna in its natural, unmodified state, before the PIN diodes are added, and then shows how the diodes are used to probe three distinct modes of operation.

REFERENCE

[1] Danesh, S.; Rahim, S.K.A.; Abedian, M.; Khalily, M.; Hamid, M.R., "FrequencyReconfigurable Rectangular Dielectric Resonator Antenna," Antennas and Wireless Propagation Letters, IEEE, vol.12, no., pp.1331, 1334, 2013.

[2] Hao, C.X.; Li, B.; Leung, K.W.; Sheng, X.Q., "Frequency-Tunable Differentially Fed Rectangular Dielectric Resonator Antennas," Antennas and Wireless Propagation Letters, IEEE, vol.10, no., pp.884, 887, 2011

[3] Chair, R.; Kishk, A.A.; Kai Fong Lee, "Comparative Study on Different Feeding Techniques for Dual Polarized Dielectric Resonator Antennas," Antennas and Propagation Society International Symposium 2006, IEEE, vol., no., pp.2495,2498, 9-14 July 2006

[4] Danesh, S.; Rahim, S.K.A.; Abedian, M.; Hamid, M.R., "A Compact FrequencyReconfigurable Dielectric Resonator Antenna for LTE/WWAN and WLAN Applications," Antennas and Wireless Propagation Letters, IEEE, vol.14, no., pp.486,489, 2015

[5] So, K.K.; Leung, K.W., "Bandwidth enhancement and frequency tuning of the dielectric resonator antenna using a parasitic slot in the ground plane," Antennas and Propagation, IEEE Transactions on, vol.53, no.12, pp.4169,4172, Dec. 2005

[6] Hoi Kuen Ng; Kwok Wa Leung, "Frequency tuning of the linearly and circularly polarized dielectric resonator antennas using multiple parasitic strips," Antennas and Propagation, IEEE Transactions on, vol.54, no.1, pp.225,230, Jan. 2006

[7] Apperley, T.; Okoniewski, M., "A frequency reconfigurable dielectric resonator antenna using controllable air gaps," Antennas and Propagation (EuCAP), 2014 8th European Conference on, vol., no., pp.2923,2926, 6-11 April 2014

[8] Chitra, R.J.; Nagarajan, V., "Frequency reconfigurable antenna using PIN diodes," Communications (NCC), 2014 Twentieth National Conference on , vol., no., pp.1,4, Feb. 28 2014-March 2 2014

[9] J.T. Bernhard, Reconfigurable Antennas. Chicago, IL: Morgan & Claypool Publishers, 2007.

[10] P. Deo, A. Mehta, D. Mirshekar-Syahkal, P.J. Massey, H. Nakano, "Beam steerable square loop antenna over hybrid high impedance surface," Electronics Letters, vol.45, no.19, pp.962-964, Sept. 2009.

[11] J. Sarrazin, Y. Mahe, S. Avrillon, S. Toutain, "Pattern reconfigurable cubic antenna," IEEE Transactions on Antennas and Propagation, vol.57, no.2, pp.310-317, Feb. 2009.

[12] Yan-Ying Bai, Shaoqiu Xiao, Changrong Liu, Xiang Shuai, and Bing-Zhong Wang, "Design of Pattern Reconfigurable Antennas Based on a Two—Element Dipole Array Model"