PERFORMANCE EVALUATION AND ANALYSIS OF FREQUENCY RECONFIGURABLE DIELECTRIC RESONATOR ANTENNA: A REVIEW

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Abstract - *Frequency reconfigurable dielectric resonator antennas (DRAs) are a type of antenna that can adjust their operating frequency without physically changing their shape or size. DRAs are made of a high-permittivity dielectric material that resonates at a specific frequency, and by adjusting the dielectric constant of the material or its dimensions, the resonant frequency of the antenna can be tuned. One way to achieve frequency reconfigurability in DRAs is by using a varactor diode, which is a type of electronic component that can change its capacitance when a voltage is applied. By placing a varactor diode in series with the DRA, the effective permittivity of the dielectric material can be changed, and the resonant frequency of the antenna can be shifted.*

Another approach to achieving frequency reconfigurability in DRAs is by using a switchable feed network, which can change the coupling between the DRA and the feedline. By switching between different feed configurations, the resonant frequency of the antenna can be changed.

Frequency reconfigurable DRAs have several advantages, including their small size, low profile, and wide bandwidth. They can also be easily integrated into wireless communication systems and have applications in mobile and satellite communication systems, radar systems, and wireless sensor networks.

Key Words: Frequency reconfigurable, resonator, antennas, wireless, communication.

1. INTRODUCTION

Wireless communication is incredibly important in today's world, and its importance is only increasing as technology advances. Wireless communication allows people to stay connected while on the move, whether it's through mobile phones or other wireless devices. This has revolutionized the way people communicate and do business, as it enables them to work from anywhere and stay connected to the internet at all times. With wireless communication, people no longer have to be tethered to a specific location to communicate or access information. This convenience has made it possible for people to work remotely, access information on the go, and stay connected with friends and family even when they are not physically close. Wireless communication has made it possible to transmit information over long distances without the need for expensive infrastructure, such as cables or wires. This has lowered the cost of communication and made it more accessible to people in remote areas who may not have had access to traditional communication methods. Wireless communication has also improved safety in many industries, such as transportation and emergency services. For example, wireless communication allows emergency responders to quickly communicate with each other and coordinate their response to a crisis. Wireless communication has enabled the development of new technologies, such as smart homes, wearables, and the Internet of Things (IoT). These technologies are transforming the way people live and work, and are opening up new possibilities for businesses and consumers alike. Overall, the importance of wireless communication cannot be overstated. It has revolutionized the way people communicate and does business, made communication more accessible and cost-effective, improved safety, and enabled the development of new technologies.

1.1. RECONFIGURABLE DIELECTRIC RESONATOR ANTENNA

Reconfigurable dielectric resonator antennas (RDRA) are a type of antenna that uses a dielectric resonator to resonate at a specific frequency. The dielectric resonator is made of a high-permittivity material and is typically in the form of a cylindrical or rectangular block.

RDRA is designed to allow its resonant frequency to be changed dynamically by using some form of tuning mechanism. This tuning mechanism can be either electrical or mechanical. The use of such a mechanism allows the RDRA to be reconfigured to operate at different frequencies, which makes it highly versatile and useful in a variety of applications.

One of the main advantages of RDRA is that it can provide high levels of performance, including high gain, low loss, and high directivity. In addition, its compact size and reconfigurability make it an attractive option for use in a variety of applications, including wireless communication systems, satellite communication systems, radar systems, and microwave imaging systems.

RDRA technology is still in its early stages of development, but it has already shown significant potential in a range of applications. As the technology continues to mature, it is expected that RDRA will become even more widely used and will play an increasingly important role in modern communication and imaging systems.

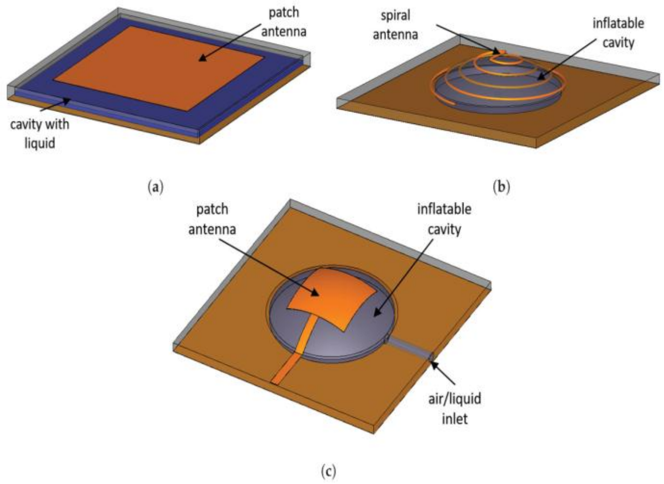

Figure-1: Reconfigurable dielectric resonator antennas

2. RECONFIGURABILITY IN PATCH ANTENNA

Reconfigurability in patch antennas refers to the ability to change the electrical properties of the antenna by adjusting its physical configuration or adding external components. This allows the antenna to operate at different frequencies or in different modes, making it more versatile and adaptable to changing requirements.

One way to achieve reconfigurability in patch antennas is by using tunable materials, such as varactors or ferroelectric materials, that can change their electrical properties in response to an external stimulus, such as an applied voltage or magnetic field. By integrating these materials into the antenna design, the resonant frequency of the antenna can be tuned over a wide range.

Another approach is to use switchable components, such as PIN diodes or MEMS switches, that can change the configuration of the antenna, such as switching between different feed points or changing the size or shape of the patch. This can also be used to create multiple resonant modes in the antenna, allowing it to operate at different frequencies.

Reconfigurable patch antennas have many potential applications in wireless communications, including frequency hopping systems, cognitive radios, and adaptive beamforming. They can also be used in other areas such as radar systems and sensing applications where the ability to change the antenna's properties can enhance performance or enable new capabilities.

2.1. RECONFIGURABLE ANTENNAS FOR COGNITIVE RADIO APPLICATIONS

Reconfigurable antennas are a type of antenna that can dynamically change their operating frequency, polarization, radiation pattern, or other parameters based on the surrounding electromagnetic environment or user requirements. These antennas have gained significant interest in cognitive radio applications due to their ability to adapt to changing radio frequency (RF) environments and provide spectrum agility.

Cognitive radio (CR) is a wireless communication technology that enables efficient and dynamic spectrum sharing among different wireless systems by utilizing the underutilized or unused spectrum. CR systems require reconfigurable antennas that can operate over multiple frequency bands, support multiple wireless standards, and provide directional coverage based on the specific communication scenario.

There are several types of reconfigurable antennas used in cognitive radio applications, including frequency reconfigurable antennas, polarization reconfigurable antennas, beam-steering antennas, and switchable antennas. Frequency reconfigurable antennas can dynamically change their resonance frequency to cover multiple frequency bands, while polarization reconfigurable antennas can change the orientation of the electric field to support different polarization schemes. Beam-steering antennas can change the direction of the radiation beam electronically by varying the phase and amplitude of the antenna elements. Switchable antennas can switch between multiple modes of operation, such as omnidirectional and directional modes, by selectively activating or deactivating certain antenna elements.

Reconfigurable antennas have several advantages in cognitive radio applications, such as improved spectrum efficiency, increased capacity, and reduced interference. These antennas can also adapt to different wireless standards and communication scenarios, which makes them suitable for future wireless communication systems.

In summary, reconfigurable antennas have significant potential in cognitive radio applications due to their ability to adapt to changing RF environments and support dynamic spectrum sharing. As wireless communication systems continue to evolve, reconfigurable antennas will play an increasingly important role in enabling efficient and flexible spectrum usage.

3. RECONFIGURABLE MONOPOLE ANTENNA

A reconfigurable monopole antenna is a type of antenna that can be adjusted or reconfigured to operate at different frequencies or with different polarization. The monopole antenna is a simple antenna that consists of a single vertical conductor mounted over a ground plane. The reconfigurability of the antenna allows it to be used in a wide range of applications, including wireless communication systems, radar systems, and satellite communications.

The reconfiguration of the monopole antenna can be achieved by changing the length or shape of the antenna, by adding or removing parasitic elements, or by changing the properties of the materials used in the antenna. These changes can be controlled by electronic switches or other devices, which can be programmed to adjust the antenna to the desired frequency or polarization.

The advantages of a reconfigurable monopole antenna include its versatility, compact size, and ease of integration with other electronic components. It can also be designed to operate in a variety of environments and conditions, including harsh weather and high temperatures.

Overall, reconfigurable monopole antennas are a promising technology for wireless communication systems and other applications that require flexible and adaptable antenna designs.

4. LITERATURE SURVEY

In the section of the literature review, we have studied past research papers re; are to Reconfigurable dielectric resonator antennas, and summary of all past research papers is given below:

Haider et al: Communication and surveillance use reconfigurable antennas. They can real-time adjust circuital and radiation properties. To accomplish radiation pattern and frequency agility, antennas must be topologically reconfigurable. To meet functionality requirements, array form, size, and grid spacing should be adjusted. Digital beam shaping in transmit and receive allows the flexible field of view and coverage specification. This entails choosing the best beam-forming algorithm and calibration technique. Reconfiguring the antenna element allows frequency, polarisation, and radiation pattern agility. Frequency agility might mean switching between operating frequency bands (connected to the sensor application) in a multifunctional system or tuning the center frequency of the instantaneous bandwidth within the entire operating bandwidth of a given communication or sensing feature. The first instance involves reconfigurability at the antenna element level, using switching components to provide optimal antenna functioning within the intended frequency ranges, and array topology level, to modify array spacing. Tunable components or substrates adjust narrowband elements' center frequencies in the second scenario.

Joseph, Silvio: This study summarises reconfigurable antenna design, optimization, and utilization methods. Reconfigurable antennas dominate modern communication systems. They provide the foundation for many future cognition-based and adaptive applications. Today's communication technology doesn't require a static communication system with one or more permanent antennas. Various antenna reconfiguration methods are suggested. These methods are electrical, optical, or mechanical. No matter the method, the antenna radiating aperture is rearranged. Graph models and neural networks can automate, control, and optimize reconfigurable antennas. These approaches on FPGAs, microcontrollers or any programmable CPU enable reconfigurable antennas to meet design goals. Eventually, reconfigurable antennas will self-adapt, learn, respond, overcome failures, and provide an efficient, dynamic, and ever-changing communication connection.

Weng, Zahriladha: This study reviews reconfigurable integrated filters and antennas and discusses current improvements and their applications. Most researchers choose microstrip structures. This construction is light, cheap, simple to make, and compatible with any planar structure. Recent research demonstrates that microstrip construction may reduce antenna size, however, creating a larger tuning range with low power and loss is a challenge. This review explains microwave filter development. It intends to provide a reference for reconfigurable integrated filter and antenna design research to improve performance and size for multifunction operating applications.

Shraddha, Pankaj: Subjective radio, space, satellite communication, and portable radio use distinct reconfigurable antennas. Reconfigurable antennas are better than other antenna methods because they may be used in several modes. Single antenna multiuse applications or customers are suitable. It offers cheaper, better communication. This article shows reconfigurable antenna characteristics. Reconfigurable antennas have considerable potential. CST Microwave Studio (CST MWS)-2018 can structure and reproduce reconfigurable antennas.

Manjula: This article compares their performance improvement strategies and reviews 5G antennas. 5G connection requirements are detailed. Centered on input ports, SISO, and MIMO are the two main 5G antenna architecture classifications. Wideband and multiband are based on frequency response. SISO antennas may be divided into single and multi-unit element antennas. SISO antennas fit 5G IoT devices. Wideband and multiband MIMO antennas may be multi-element or metal-rimmed. MIMO antennas are optimal for smartphones, although base stations may employ huge ones. Carrier aggregation boosts MIMO metal rim antenna transmission rates. Orthogonal polarisation increases separation and performance. Antennas are also classified by shape.

Elizaveta, Huang: This study detailed state-of-the-art liquid dielectric reconfigurable antenna design, optimization, and application approaches. Modern communication technology's shrinking hardware makes permanent antennas unsuitable for communication networks. Liquid dielectric materials provide a new radiation control and reconfigurability mechanism that complements previous approaches. Liquid-based and liquid-assistive antenna reconfiguration methods used liquid dielectrics. The liquid-based approach uses a liquid dielectric substance as the radiating structure. In the liquid-assisted method, a liquid dielectric substance modifies the local currents of a metal-based antenna to change its radiation characteristics. This study covered reconfigurable antenna design principles, benefits, and drawbacks. Liquid dielectric reconfigurable antennas provide greater efficiency and operating bandwidth than electrical switch-based reconfiguration techniques, despite certain technical and practical limitations.

Marie et.al: This study reviewed all CR reconfiguration methods. CR communication uses frequency-reconfigurable antennas. Some have sensing and communication portions on the same substrate but different antennas. Single-port antennas perform sensing and communication in the 3rd category. Every antenna must be changeable electrically, optically, and physically, using smart materials, and most recently, excitation switching. MEMS, PIN diodes, Varactors, FET switches, and photoconductive switches may reconfigure electrically and optically. Structure variation and smart materials enable physical reconfiguration. The latest method, excitation switching reconfiguration, switches excitation to determine which antenna can connect with the sensor antenna. Size, UWB and NB coverage, complexity, losses, switching speed, isolation, power needs, efficiency, etc. are studied for many antennas. This study analyses the benefits and downsides of each approach to help researchers work within application limits. Reconfigurable antennas should adapt to their environment and provide an energy-efficient communication connection between devices. Software-defined control and machine learning of the antenna system will advance reconfiguration. Multi-band wearable antennas may benefit from reconfiguration.

Anjana: This work classifies and reviews reconfigurations. The antenna's structural design and reconfigurability methods—electrical, optical, and mechanical—are detailed. Reconfigurable antennas adapt to system needs. Compound reconfigurable antennas change their dual properties inside the same antenna system. Reconfigurable antenna research has mostly concentrated on antenna shapes and feeding methods, although gain increase, wideband operation, and high-power handling techniques are also important. Understanding reconfiguration methodologies and commercial applications of reconfigurable antennas is important as the changing environment increases demand for multifunctional antenna systems.

Rohini, Sonal: As shown in Fig. 4, a surface-mount assembly instrumentation transmits signals from the feed-other line's end. To create a unique multiband antenna, two-folded arms with a microstrip stub between them are used as the diverging stub. Misusing this structure causes additional surface current techniques and variable resonance frequencies [4, 5]. The initial length of the rolled-up arms is chosen to match the WLAN band frequency (lg/4 at the center waveband of 2.4 GHz) and the length of the microstrip stub between the two-folded arms matches the WiMAX band frequency (lg/4 at 3.5 GHz), where lg is the radio-controlled wavelength [8]. A constant study has been conducted to find an appropriate compromise between the antenna frequency responses at both bands. Zeeland IE3D simulates proposed reconfigurable antennas.

Karthika, Kavitha: Reconfigurable antennas are the most modern antenna design to meet wireless communication system needs. This report examines reconfigurable antenna design for wireless applications. This study examined reconfigurable antenna designs, switching processes, and antenna performance enhancement methods. Thus, the reconfiguration kind, size, and form of radiating structures must be chosen for the final use. In reconfigurable antenna designs, effective methods should reduce mutual coupling and improve gain, bandwidth, and isolation. Combining reconfiguration or multi-functional capabilities on a single substrate to provide acceptable radiation characteristics in all states would enable enhanced wireless communication. So, this effort will allow antenna researchers to develop new concepts to surpass benchmark results in future antenna research.

Navneet et.al: A reconfigurable frequency metasurface-based microstrip patch antenna is rotatable. A microstrip patch antenna has a circular ground plane and a metasurface on a first and second substrate, respectively. Rotating the metasurface structure achieves frequency reconfiguration, according to research. Fractional tuning and bandwidth of 20.2% and 1.12 GHz, respectively, allow frequency reconfiguration in the 4.97 to 6.09 GHz range.

5. CONCLUSION

Reconfigurable dielectric resonator antennas (RDRA) have a promising future as they offer the potential to enhance the functionality of conventional antennas by changing their physical properties. RDRA technology has been gaining increasing attention from researchers and industry experts due to its ability to operate over a wide range of frequencies and its adaptability to different wireless communication systems. RDRA technology has the potential to improve the performance of 5G wireless communication systems by providing higher data rates and increased bandwidth. RDRA technology can be used in satellite communication systems to provide better signal quality, higher data rates, and reduced power consumption. RDRA technology can be used in IoT devices to enable wireless communication between devices and improve the overall performance of the system. RDRA technology can be used in radar systems to improve the resolution and accuracy of the system. RDRA technology can be used in medical applications, such as wireless medical devices and implantable antennas, to enable wireless communication between devices and improve the overall performance of the system.

REFERENCE

[1] Nadeem, Q.-U.-A.; Kammoun, A.; Debbah, M.; Alouini, M.-S. Design of 5G full dimension massive MIMO systems. IEEE Trans. Commun. 2018, 66, 726–740.

[2] Bhartia, P.; Bahl, I.J. Frequency agile microstrip antennas. Microw. J. 1982, 25, 67–70.

[3] Bernhard, J.T. Reconfigurable Antennas; Morgan & Claypool Publishers: San Rafael, CA, USA, 2007.

[4] Peroulis, D.; Sarabandi, K.; Kateh, L.P.B. Design of reconfigurable slot antennas. IEEE Trans. Antennas Propag. 2005, 53, 645–654.

[5] Christodoulou, C.G.; Tawk, Y.; Lane, S.A.; Erwin, S.R. Reconfigurable antennas for wireless and space applications. Proc. IEEE. 2012, 100, 2250–2261.

[6] Balanis, C.A. Antenna Theory Analysis and Design, 4th ed.; John Wiley & Sons: New York, NY, USA, 1998.

[7] Bernhard, J.T. Reconfigurable Antennas;Wiley: New York, NY, USA, 2005.

[8] Grau, J.R.; Lee, M.J. A dual-linearly-polarized MEMS-reconfigurable antenna for NB MIMO communication systems. IEEE Trans. Antennas Propag. 2010, 58, 4–17.

[9] Tawk, Y.; Costantine, J.; Christodoulou, C.G. A varactor based reconfigurable filtenna. IEEE Antennas Wirel. Propag. Lett. 2012, 11, 716–719.

[10] Nikolaou, S.; Bairavasubramanian, R.; Lugo, C.; Carrasquillo, I.; Thompson, D.C. Pattern and frequency reconfigurable annular slot antenna using PIN diodes. IEEE Trans. Antennas Propag. 2006, 54, 439–448.

[11] Parchin, N.O.; Al-Yasir, Y.; Abdulkhaleq, A.M.; Elfergani, I.; Rayit, A.; Noras, J.M.; Rodriguez, J.; Abd-Alhameed, R.A. Frequency reconfigurable antenna array for mm-Wave 5G mobile handsets. In Proceedings of the 9th International Conference on Broadband Communications, Networks, and Systems, Faro, Portugal, 19–20 September 2018.

[12] Ojaroudi, N.; Parchin, N.O.; Ojaroudi, Y.; Ojaroudi, S. Frequency reconfigurable monopole antenna for multimode wireless communications. Appl. Comput. Electromagn. Soc. J. 2014, 8, 655– 660.

[13] Ojaroudi, N.; Ghadimi, N.; Ojaroudi, Y.; Ojaroudi, S. A novel design of microstrip antenna with reconfigurable band rejection for cognitive radio applications. Microw. Opt. Technol. Lett. 2014, 56, 2998–3003.

[14] Hussain, R.; Sharawi, M.S.; Shamim, A. An integrated four-element slot-based MIMO and a UWB sensing antenna system for CR platforms. IEEE Trans. Antennas Propag. 2018, 66, 978–983.

[15] Hussain, R.; Khan, M.U.; Sharawi, M.S. An integrated dual MIMO antenna system with dual-function GND-plane frequency-agile antenna. IEEE Antennas Wirel. Propag. Lett. 2018.

[16] Hinsz, L.; Braaten, B.D. A frequency reconfigurable transmitter antenna with autonomous switching capabilities. IEEE Trans. Antennas Propag. 2014, 62, 3809–3813.

[17] Hannula, J.-M.; Saarinen, T.; Holopainen, J.; Viikari, V. Frequency reconfigurable multiband handset antenna based on a multichannel transceiver. IEEE Trans. Antennas Propag. 2017.

[18] Nguyen-Trong, N.; Piotrowski, A.; Fumeaux, C. A frequency reconfigurable dual-band low-profile monopolar antenna. IEEE Trans. Antennas Propag. 2017, 65, 3336–3343.

[19] Boukarkar, A.; Lin, X.Q.; Jiang, Y.; Chen, Y.J.; Nie, L.Y.; Mei, P. Compact mechanically frequency and pattern reconfigurable patch antenna. IET Microw. Antennas Propag. 2018, 12, 1864–1869.

[20] Sam, S.; Kang, H.; Lim, S. Frequency reconfigurable and miniaturized substrate integrated waveguide interdigital capacitor (SIW-IDC) antenna. IEEE Trans. Antennas Propag. 2014, 62, 1039–1045.

[21] Anand, S.; Raj, R.K.; Sinha, S.; Upadhyay, D.; Mishra, G.K. Bandwidth reconfigurable patch antenna for next generation wireless communication system applications. In Proceedings of the International Conference on Emerging Trends in Communication Technologies (ETCT), Dehradun, India, 18–19 November 2016.

[22] Anagnostou, E.; Torres, D.; Sepulveda, N. Vanadiomdioxde switch for a reconfigurable bandwdith antenna. In Proceedings of the Loughborough Antennas & Propagation Conference (LAPC 2017), Loughborough, UK, 13–14 November 2017.

[23] Meng, L.; Wang, W.; Gao, J.; Liu, Y. Bandwidth reconfigurable antenna with three stepshaped slots. In Proceedings of the Sixth Asia-Pacific Conference on Antennas and Propagation (APCAP), Xi'an, China, 16–19 October 2017.

[24] Chen, S.-Y.; Chu, Q.-X.; Shinohara, N. A bandwidth reconfigurable planar antenna for WLAN/WiMAX applications. In Proceedings of the Asia-Pacific Microwave Conference (APMC), New Delhi, India, 5–9 December 2016.