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Review Analysis of Dielectric Resonator Antenna

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Abstract-— **In this paper , we are going to discuss the basic parameter of Dielectric Resonator Antenna ,their different types . This type of antenna have advantage of different feeding techniques. DRA array is also discussed in this paper. We will come to know the effect of circular polarization on DRA in this paper . we will end our discussion with properties and application of DRA**

Index Terms— Dielectric Resonator Antenna (DRA), Circularly Polarized(CP), Rectangular Dielectric Resonator Antenna(RDRA), Cross shaped Dielectric Resonator Antenna (XDRA)

I. INTRODUCTION

Hertz showed reflection, refraction, and polarization, demonstrating that radio waves were identical to light except for their much longer wavelength. Hertz swung the odds in Maxwell's favour. Hertz was known as the "Father of Radio." However, Hertz's apparatus remained a laboratory mystery for nearly a decade, until Guglielmo Marconi, then 20 years old, replicated Hertz's experiment. Marconi soon added tuning, massive antennas, and ground systems for longer wavelengths, allowing him to communicate over long distances.[3] An antenna is a part of a device that is used to transmit or receive electromagnetic waves. To put it another way, the antenna is an electromagnetic transducer that converts directed waves inside a transmission line to radiated free-space waves in the transmitting mode and free-space waves to guided waves in the receiving mode.[1] The crucial thing to be noted that radiation of antenna took place from current. Controlling currents to achieve the desired radiation distribution, also known as the pattern, is what design is all about.[2] For a coordinate system based on the antenna, spherical waves propagate in the radial direction. Plane waves can approximate spherical waves over long distances. Plane waves are advantageous because they make the issue easier to understand. They aren't physical, though, since they necessitate infinite energy.[2]

Charge carriers are primarily inserted into a dielectric from electrical contacts or other external sources because the energy band gap in a dielectric is relatively wide, necessitating a greater amount of energy for such band-to-band transitions. A material is made up primarily of atoms or molecules with electrons and nuclei.[4]] Any dielectric structure may become a radiator at given frequencies by using the right excitation technique. Furthermore, by lowering the dielectric constant, this radiation could be maintained over a broad frequency spectrum. The size of the dielectric resonator is inversely proportional to the relative permittivity of the constitutive material for a desired frequency. Dielectric resonators function in a similar way to cavity resonators in terms of basic principles.[5] Long, McAllister, and Shen conducted the first systematic analysis of dielectric resonators as radiating elements in the 1980s. The majority of research in the late 1 980s and early 1 990s focused on studying the different modes of excitation of dielectric resonator antennas with simple shapes, investigating a variety of feed mechanisms, and using analytical and numerical techniques to determine the input impedance, Q factor, and radiation patterns of dielectric resonator antennas.[7]

A DRA is a microstrip patch radiator that has been modified. As compared to a microstrip patch radiator, the basic concept of radiation and resonant modes in a DRA are entirely different. A DRA, unlike a microstrip patch, has no metallic parts in its radiating structure, so it has no ohmic losses. As a result, assuming no or minimal losses in the dielectric material, a DRA should be more efficient than a microstrip, particularly at millimetre-wave frequencies. The DRA reveals a smaller radius, a wider bandwidth, and lower gain. In both principal planes, the 3 dB beamwidth of a DRA is greater than that of a microstrip patch. As compared to a microstrip patch antenna, the DRA has a higher performance, which becomes more significant as the frequency of operation increases. In certain instances, DRAs are still difficult to complete. In recent years, there has been a greater emphasis on improving antenna band-width and gain, which are more important to the needs of modern wireless applications.[6]

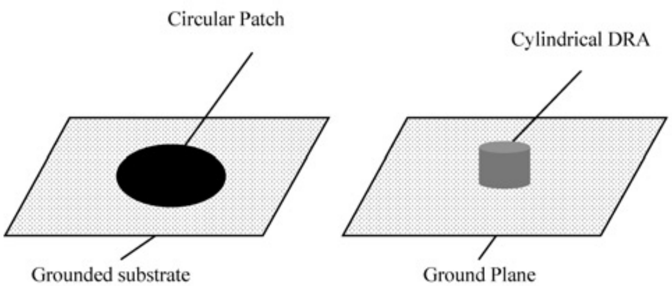

Fig. 1 Conventional geometries of microstrip and DRAs[6]

In this Paper , we are going to dicuss about basics of DRA their properties and how they can be usefull in wireless communication . we will also discuss various types of DRA and their properties . We can feed DRA by various methods later in this paper we will discuss all of them. History of antenna and DRA are also discussed in introduction part itself. The most important question is if we have microstrip patch antenna then why we need DRA. This answer of why is also provided in paper. DRA can be used in various parts and field .

1.1. DRA Types

The cylindrical and rectangular radiating dielectric resonators are the most common. This segment will go through in this paper in detail. The related resonant frequencies are calculated using design equations. Spherical/hemispherical, cross-shaped, and supershaped dielectric resonators are more complex.

- ***Rectangular DRA***

While there are several different shapes to choose from, there have been very few studies on rectangular-shaped DRAs so far. Rectangular DRAs, on the other hand, have functional advantages over cylindrical and spherical DRAs. In the case of rectangular DRAs, for example, mode degeneracy can be avoided by carefully selecting the three dimensions of the resonator. In contrast to spherical or cylindrical DRs, there is no systematic grouping of modes for rectangular DRs. Three independent dimensions make up a rectangular DR. As a result, a DR's modes can be TE in any of three dimensions.[8]

The cumulative stored energy and the power radiated by the DRA can be used to calculate the DRA's radiation Q factor. If the dielectric constant of the DR is strong, the majority of the stored electric energy is stored within the resonator. Because of the fields within the resonator, the stored electric energy can be conveniently computed. Controlling the length of the slot allows for easy adjustment of the coupling between DRA and the slot. If the dimensions of a slot are such that the maximal coupling to the DRA is greater than the critical coupling, varying the location of the DRA with respect to the slot is a simple way to achieve the critical coupling.[8] The rectangular-shape DRA of permittivity, εr = 55, was fabricated for 3.5 GHz operation in [9]. For microwave applications, the RDRA may be used as a transponder.

- ***Cylindrical DRA***

A cylindrical dielectric resonator (DR) with height h, radius a, and dielectric constant ϵ_r makes up the antenna. A coaxial connector feeds DR, which is mounted on top of a ground plane. The cylindrical DRA's key benefits are its ease of construction and ability to excite several modes. [10] The $TE_{01\delta}$ mode in a cylindrical DR is traditionally used in filter design due to its high quality (Q) factor.[11]

DRAs come in a variety of sizes, but cylindrical structures are preferred because they have a high propensity for replacing waveguide cavity resonators when made from materials with a high dielectric constant. As compared to other types of available structures, cylindrical DRA is the shortest. CDRA's aspect ratio is determined by its height and radius. The cylindrical radiator's resonant frequency is determined by the aspect ratio. Lower order modes are supported by both rectangular and cylindrical DRA. However, when operating in the same mode setup, cylindrical DRA has a higher impedance BW than rectangular DRA. Turning on and off various combinations of probes in a cylindrical DRA will even electronically direct the radiation pattern.[12]

Hemisphere and Cross-Shaped and Supershaped DRAs

As run in TE_{111} mode, a hemispherical DR sitting on a ground plane has also been shown to be a strong radiator.[13] The hemispherical DR antenna has the easiest structure for analytical study among the different DR antenna shapes. [14] The broadside TE_{111} mode of the hemispherical DR antenna with an airgap has been proposed by K.L.Wong in [13] . In [15] we will learn how we can use glass dielectric resonator as light cover . A dual-band hollow and solid hemispherical glass DRAs were also explained by the authors of [15]. A slot excites the hollow hemisphere, while a probe-fed DRA excites the solid one. An LED was introduced into the air gap through the ground plane using the clarity of the bottle, resulting in a DRA that can be used as a light shield.[5]

The circularly polarised antenna is best designed with a cross-shaped dielectric resonator. This structure also gives the antenna more design freedom and makes it easier to manufacture.[16] The downside of the single point feed is

that it can only achieve a narrow CP bandwidth. However, a CP bandwidth of 5% has been obtained using the aperture-fed cross shaped dielectric resonator antenna (XDRA). This is far more than the average 1-2 percent CP bandwidth that a single-point fed microstrip patch antenna can achieve.[17]
The key benefit of the presented supershaped DRA is that it is made of plastic (PolyVinyl Chloride (PVC)) as the dielectric fibre, making it very cost efficient and easy to manufacture. Using a supershaped dielectric resonator, the recorded impedance bandwidth is increased by 74%.[5] The authors of [18] tried their best to explain the concept of A plastic-based supershaped DRA. The most popular dielectric resonator (DR) configurations (hemispherical) have been updated in recent years, mainly in the search for increased operating bandwidths. [18]

2. FEEDING MECHANISM

One of the most significant benefits of DRA technology is the ability to excite the radiating modes of a dielectric resonator using a variety of feeding techniques.

- ***Probe fed DRA***

Coaxial feed, also known as probe feed, is a popular method of feeding dielectric resonator antennas. The probe fed system was the first feeding procedure used on DRA. The DR is immediately disposed on the ground plane in this configuration, and it is excited by a coaxial feed through the substrate. The coaxial probe may either be inserted into the DR or positioned next to it. The primary advantage of a probe that penetrates the DRA is that it provides high coupling to the DR, resulting in high radiation efficiency. The biggest disadvantage of this setup is that it necessitates drilling a hole in the DRA. The length and radius of the drilled hole must match the length and radius of the probe, otherwise the effective dielectric constant of the resonator will be changed, creating a change in the antenna's resonance frequency. Furthermore, it should be noted that drilling a hole in the DR complicates and increases the cost of the production process.[5]
The probe can be thought of as a vertical electric current located to obtain a tight coupling to the DRA. When changing the height and diameter of the probe, the degree of coupling is optimised. Different modes may be excited depending on the form of the DRA and the position of the probe; for example, when it is fed axially, only TM modes are excited. To be more specific, if the TM_{01} mode is excited, the feed probe should be placed in the middle, resulting in quarter wavelength monopole-like far field radiation patterns. When HEM_{11} (TM_{110}) mode is needed, on the other hand, the feed probe should be placed close to the peripheral boundary to produce broadside radiation patterns. This method is especially useful for dealing with fabrication problems at lower frequencies, but it is also effective and results-oriented at higher frequencies.[19] The input impedance of the DRA can be tuned and, as a result, the resonance frequency can be regulated by optimising the duration and direction of the feeding probe.[20]

- ***Microstrip Transmission Line-Fed DRA***

Printed transmission lines are another choice for feeding the DRA. The dielectric resonator is directly mounted on the transmission line printed on the PCB substrate in traditional microstrip line feed DRAs. The author of [21] shows first reported DRAs fed by microstrip line fed. The key disadvantage of the microstrip transmission line feed is that it is not separated from the dielectric resonator, which may have an effect on the DRA's radiation efficiency. Furthermore, when a dielectric resonator is placed directly on top of a transmission line, an unwanted air gap is formed between the resonator and the PCB substrate. The resonator is directly on the PCB substrate in a conformal transmission line-fed DRA, and the feeding microstrip is bent over the resonator. The input transmission line is combined with the DR without having an air gap using this setup.[5] The easiest approaches are direct and proximity couplings. The magnetic fields in the DRA are excited, resulting in a short horizontal magnetic dipole.

- ***Coplanar-Waveguide-Fed DRA***

The energy is effectively coupled to the DRA by the coplanar ring. By progressively slipping the DR part over the ring, the coupling degree and desired mode excitation can be obtained. The requisite resonance frequency and radiation patterns can be obtained by moving the loop from the edge to the middle.[19] A coplanar waveguide (CPW) circular-loop network that feeds a circular DRA was first discussed and proposed by the authors of [21], where a coplanar waveguide (CPW) circular-loop network that feeds a circular DRA is provided. The key benefit of CPW excitation is that the coupling slot underneath the dielectric resonator can be changed to improve the DRA's efficiency.

- ***Slot-Fed DRA***

The most common method of feeding DRAs is through a slot in the ground plane. Aperture coupling is the name for this type of excitation. The resonant modes of the DR are coupled to the guided wave propagating along the transmission line via the slot.[5] It's a well-known

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coupling strategy that has the benefit of keeping the feed network below the ground plane, which eliminates unintended radiations that induce distortion and weaken the pattern structure. The aperture at the DRA centre acts like magnetic current flowing parallel to its length while HEM_{11} or TM_{110} is the dominant resonant mode, excitating the magnetic fields in the DRA body and triggering broadside radiation patterns in the far region.[19]

- ***Dual Port Excitations***

Dual ports excitation is favoured over single port excitation for circular polarisation because it yields a larger 3dB Axial Ratio (AR) bandwidth. Highly decoupled ports are normally needed for both circular and linear polarizations.[19]
Dual port excitation can be achieved by mixing two separate or identical types of feeding. The hybrid configuration of coaxial probe and aperture slot provides better port separation, but it has fabrication restrictions. The other approach for dual port excitation is a mixture of an aperture slot and a coplanar waveguide. This method still provides effective port separation, although it is limited to a few applications. We can also get dual port excitation technique by using similar combination of two aperature slot it reduces the disadvantages of above two by making fabrication simple and easy but port isolation is poor

- ***Circular Polarization in DRA***

The circular polarisation mode, in which the direction of the tip of the E vector rotates around the propagation axis as a function of time, is preferred for many communication schemes. Since circular polarisation (CP) operation eliminates the need to constantly align the two apertures, which would otherwise be necessary to optimise the receive power, this is the case for satellite and ground station antennas.[22] Because of its insensitivity of transmitter and receiver orientations, the circularly polarised (CP) device is better suited to certain uses, such as satellite communications. The dualband CP DRA, on the other hand, has gotten very little coverage so far.[23] One of the benefits of DRAs is that they can effectively regulate their polarisation. Some feed structures are especially proposed to produce CP waves, given the broad range of feed structures available to DRAs.[19]
Now we are going to discuss how to design Circularly polarized DRA using different techniques

2.1. Single Feed Technique

A single feed positioned at a position where two orthogonal modes can be excited can be used to create circularly polarised DRAs. The technique for producing circular polarisation with a single excitation relies on exciting two spatially orthogonal and phase quadrature quasi-degenerate modes in the dielectric resonator antenna. Single-point-fed dielectric resonator antennas depend on the configuration of the dielectric resonator antenna itself to produce the necessary spatial orthogonal modes in phase quadrature in order to radiate circular polarisation.[9]

2.2. Dual Feed Technique

A easy yet efficient method for achieving circular polarisation of the radiated electromagnetic field is to excite a DRA using two ports with a 90 phase shift. (5) The generation of orthogonal modes in phase quadrature is transferred to the feed by using a dual point feed to excite the dielectric resonator antenna. This is usually accomplished by using square or circular symmetry dielectric resonator antennas.[9] The authors of [24] well explained the Dual Feed Technique.

- **DRA Array**

Dielectric resonator antennas are low-gain elements, and arrays of dielectric resonator antennas, like all low-gain elements, can be used to increase directivity. The gain of a single element DRA can be as high as 5 dBi, which can be improved with an array structure. Certain basic laws must be considered in order to comprehend how an array works. The overall radiation pattern of DRA, like that of other antenna arrays, is determined by the radiation pattern of a single element multiplied by the array factor, which is:
$E = n \times E_0 \times AF$
Where E is overall radiated electric field , E_0 is Electric field at same point produced by single DRA at the centre of array, and AF is Array factor[19]

- **Linear Array**

For applications requiring fan-shaped radiation patterns, linear arrays are used. A series or corporate power-divider network may be used to feed the arrays. Series feeds deliver more lightweight, lower-loss architectures, but due to their intrinsic beam squint with frequency, series-fed arrays have reduced bandwidth. Corporate feeds have wider-band efficiency at the expense of higher insertion loss and the need for more room.[9]

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- **Planer Array**

Pencil-beam radiation patterns of low to high directivity are generated using planar arrays. Because of the additional difficulties involved in using dielectric resonator antennas in arrays, the number of fabricated planar dielectric resonator antennas that have been reported is very restricted. [9]

Just a few dielectric-resonator-antenna components make up the bulk of these planar arrays. This emphasises the fact that dielectric-resonator-antenna array technology is still in its early stages, and further research is needed to solve some of the difficulties associated with fabricating large quantities of dielectric resonator antenna components and integrating them into an array.[19]

3. PROPERTIES OF DRA

Since a dielectric resonator in an open space may have low radiation Q-factors, it can be used as a resonant antenna. Tiny footprint, no conductor loss, and mechanical simplicity are all advantages of dielectric resonator antennas. The radiation Q-factor of open dielectric resonators is highly dependent on the permittivity of the resonator, and it decreases as the permittivity decreases. Since a resonant antenna's operating frequency bandwidth is inversely proportional to the value of the radiation Q-factor.[25]

The scale of DRA is determined by the materials' resonant frequency and dielectric constant (0/€r). DRA uses a variety of feeding systems to have high radiation efficiency as well as a high degree of freedom and versatility. Due to the high permittivity of the steel, DRA has a high fabrication expense. Due to material rigidity, it is difficult to build a changed form, and it is also difficult to obtain precise dielectrics.[26]

4. DRA APPLICATION

Due to many appealing characteristics such as high radiation efficiency, light weight, and low profile, dielectric resonator antennas (DRA) have gotten a lot of attention in the last two decades. The DR antenna can be made in a variety of shapes and powered by a variety of feeding mechanisms. Recently, one of the most important aspects of DRA science has been bandwidth. [27] Since there are no conductors or surface wave leakage, the dielectric resonator antenna is ideal for low-loss applications. Many systems' frequency spectrum of interest has steadily advanced upward to the millimetre and near millimetre range, as observed.[26]

Just a few studies have been published on the use of dielectric resonator antennas (DRAs) as microwave RFID tag antennas to overcome the issues listed. Despite the fact that DRAs require metallic ground planes to operate, this property qualifies them for RFID of metallic artefacts. Small height, light weight, low profile, resistance to detuning, high radiation efficiency, and availability in different geometries are all inherent advantages. [28] Since its Q-factor can be rendered very high, the dielectric resonator (DR) has historically been used in filter and oscillator applications. [11]

In general, DRs can exhibit infinite resonant modes as ideally isolated electromagnetic devices. The DRs can be used as resonant cavities or effective radiators by appropriately exciting such resonant modes. Thus, knowing the antenna's resonant modes allows us to qualitatively predict antenna activity and estimate the emitted far field, which is crucial for antenna design. In the case of the circular cylindrical resonator, for example, the TE01, TM01, and HE11 modes have become the most widely used in radiation applications and perform well.[29]

5. CONCLUSION

We started our paper with history of antenna and brief introduction about antenna and their radiation phenomena. Then we give short introduction about dielectric and dielectric resonator . After all study and discussion the conclusion for this paper is DRA have broad application in various fields due to their various properties . The development in DRA is increasing day by day . DRA offers various advantages like their compatible size, low conduction loss, circular polarization and many more.

The various types of DRA were discussed in this paper with advantages and disadvantages of each . later we discuss application of each types . we also mentioned the mode of operation of each type. Then we came to the feeding mechanism , Feeding is also a advantages of DRA for various application . we also discussed the advantages of different feeding technique and where they were firstly used. Then we clear the concept of circular Polarization in DRA. DRA array were also briefly discussed and we end our discussion with Properties and Application of DRA.

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