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A Review on Dielectric Resonator Antenna & Its Industrial Applications

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Abstract—This Paper presents an analysis of investigation on dielectric resonator antenna (DRA's) over the last three to four decades. In every decade the research would come up with new trends. The current status of the dielectric resonator antenna technology is now reviewed. Always the evaluation has been done on the foundation of around vital parameters that include Bandwidth, Efficiency, Realized Gain, Dielectric constant, dimensions, and DRA material used**.**

This paper includes a comparison and designed of various configurations of DRA's for various applications have been appraised. From the comparison, it is clear that Weighted configuration of rectangular DRA gives the best results. It encompasses three rectangular DRA of different dimensions with dielectric constant 2.1 piled together. It works in the Bandwidth range of 6 MHz giving a Peak Realized Gain of 6.47 dB at 5.7 GHz. The enhanced Bandwidth and Gain is achieved if the dielectric constant of the material is decreased, however, the dielectric constant antenna is inversely proportional to the size of the antenna. Hence, there is a steadiness between the size and the Bandwidth depending on the requirement.
Keywords— Dielectric materials, Dielectric resonator antennas, Peak realized gain.

I. Historical Review

In late 60's the dielectric resonator have been used as high Q-factor in microwave-circuit applications due to low – loss ceramics. Dielectric Resonators have more compact substitutes to waveguide- cavity resonator and more responsive to printed – circuit integration. For relatively very high dielectric constant ($\mathcal{E}r \geq 35$) the cylindrical Dielectric resonator antennas are typically used. The maximum radiation and high quality factor it can be achieved by the enclosing DRA's in metal enclosures. By removing shielding and proper feeding to excite the appropriate mode these resonators are efficient radiators. The radiation could be maintained over a wide range of frequencies only by reducing the dielectric constant. In early 1980's the resonator was found to a good. It was also examined that the various characteristics of DRA's like cylindrical, Rectangular and hemispherical shapes give the eminent result in terms of high gain and also provides an alternative to Low gain elements like microstrip patches, monopoles and dipoles. In late 80's and early 90's the researchers focused and analyze the different modes of excitation, that can be possible with simple shapes and also analyze variety of feed mechanism and also applying the numerical techniques to improve the Q factor, gain and radiation pattern of the antenna. In mid-90's work started towards the linear and planner arrays of DRA's. This period also worked upon the low profile compact designs and mutual coupling of circular or rectangular shapes DRA's

Now in new millennium research has taken another challenge towards the involvement on new resonator antenna shapes, including spiral, conical, elliptical and stair-stepped shapes or say more hybrid structure.

II. Introduction to DRA

DRA Signifies Dielectric Resonator Antenna. The Ceramic material of various shapes is used in Dielectric resonator antenna, which produces the standing waves inside the ceramic material. From the transmitter circuit the Radio waves are inserted in the resonator material and bounce backward and forward between the resonator walls, forming standing waves. Dielectric Resonator Antenna works at the range of microwave frequencies /higher frequencies from (300MHz-300GHz). One of the most prominent features of Dielectric Resonator Antenna (DRA's) is that it produces low ohmic losses at high frequencies. DRA's are available in various shape and sizes like it could be Rectangular, circular and various Shapes as shown in Fig1.

Fig.1. various shapes of DRAs

There are two magnificent properties of DRA's.
These are:

1) Size: The size of the antenna is inversely proportional to the dielectric constant.
2) Q-Factor: The losses in DRA are inversely proportional to the Q-factor of the material used.

Every single mode of a Dielectric resonator antenna has a unique internal and associated external field distribution. Therefore, by exciting different modes of a Dielectric Resonator antenna, different radiation characteristics can be obtained. By choosing the resonator parameter over a wide range the operating bandwidth of a DR antenna can also be diverse. For example, by the suitable choice of the dielectric constant of the resonator material the modes of the lower bandwidth can be easily varied from a fraction of about 10% or more of a Dielectric resonator antenna.
DRA Consists highly attractive antenna features as they proposed various advantages over traditional antennas. These advantages are small size, low cost, high radiation efficiency, Low conductor losses, and a wide variety of feed mechanisms DRA's offer very wide range of applications like direct digital broadcast, video conferencing, satellite communications, and wireless and radar applications as they require wide bandwidth. The DRA achieved wideband for low values of dielectric constant, as it is known that the bandwidth of the DRA is inversely proportional to the dielectric constant. There are multiple enhancement techniques have been offered to stretch the bandwidth of the DRA such as notched DRA, multilayer, multi permittivity DRA and parasitic DRA. By adopting new feed techniques the bandwidth of a DRA can also be enhanced.

III. FREQUENCY RANGE

The antenna has Innumerable features where it can operate over a wide range of frequencies. The size and weight are often limiting factors of physical properties of antenna at lower frequencies; on the other hand, the antenna design often dominates the mechanical tolerance and electrical losses at higher frequencies.
The maximum dimension (D) is related to the free-space resonant wavelength (λ_0) by the approximate relation $D \infty \lambda_0 \varepsilon r^{-0.5}$ is the important characteristic of dielectric resonator antennas. The Ɛr is the dielectric constant of the dielectric resonator antenna. The radiation efficiency of a dielectric resonator antenna is not significantly affected by the dielectric constant, a wide range of values can be used (low-loss microwave dielectric material is commercially available with values ranging from $2 < \varepsilon r < 140$).
Though, the bandwidth of the dielectric resonator antenna is inversely related to the dielectric constant, and may limit the choice of values for a given application. The size of dielectric resonator antenna can be considerably reduced with the use of a material with a high dielectric constant, making it feasible for low-frequency operations. There are many published designs of dielectric resonator antennas operating at frequencies from 1 to 40 GHz, with dimensions ranging from a few centimeters down to a few millimeters, and dielectric constants approximately ranging from $8 \leq \varepsilon r \leq 100$.
55 MHz is the lowest published frequency for which a dielectric resonator antenna has been designed and fabricated. The dielectric resonator antenna, intended for use in a radar application. It consisted of a water-filled (Ɛr~84) cylindrical plastic tube, having a diameter of 550 mm and a height of 200 mm mounted on an octagonal ground plane (800 mm across the flat edges). The practical designs in the HF band (3-30 MHz) are achievable using their dielectric-resonator-antenna configuration. The highest published frequency for dielectric resonator antennas is currently 94 GHz, where an array of 128 rectangular dielectric resonator antennas (1 mm x 1. 1 mm x 0. 16 mm high) was etched on a high-resistivity silicon substrate using micromachining techniques. The array was designed as a feed for a reflector antenna, and was found to have better radiation efficiency than corresponding microstrip array design. (Dielectric resonator antennas have less conductor loss, and do not suffer from surface-wave losses.) The use of micro-machining techniques can ensure fine fabrication accuracy, which should allow the upper frequency limit of dielectric resonator antennas to extend beyond 1 00 GHz. Very few antenna elements can boast such a wide frequency range for practical designs as has been demonstrated by the dielectric resonator antenna

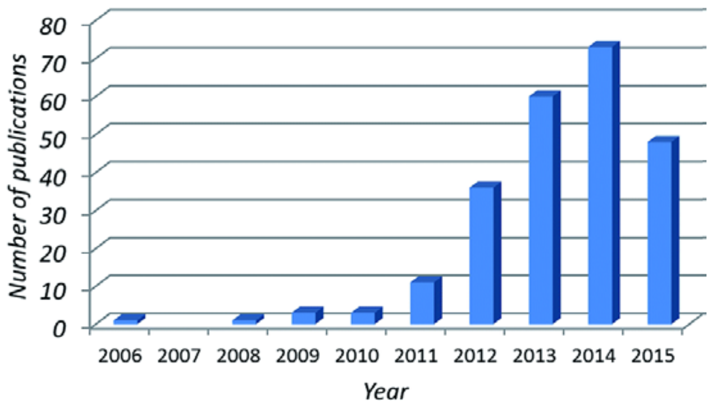

Fig2: Dielectric resonator antenna publications. [1]

IV. Low- Profile and compact Design

For a given dielectric constant, the aspect ratio of most shapes of DRA's can be altered while maintaining the same resonant frequency. A long, thin DRA can thus have the same resonant frequency (not bandwidth) as a low, wide dielectric resonator antenna. This allows for a certain degree of flexibility in shaping the DRA's to match specific requirements. This segment inspects DRA's designed with either a low profile or a compact size and climaxes the achievable bandwidth performance.

V. Low-Profile / Dielectric Resonator Antennas

The dielectric resonator antenna can be made very thin, and by using a high dielectric constant in wide applications needing low antenna profiles, the other DRA's dimensions can be kept small. There are various examples of low-profile dielectric resonator antennas of different shapes.

VI. COMPACT DRA'S

Thera are Abundant submissions, for wireless consumer, they require compact antennas to be integrated into small packages, such as cell phones, laptops, or other portable devices. In addition to using high dielectric constants to reduce the size, dielectric resonator antennas can be made compact by the judicious application of metal plates. Another technique for size reduction involves removing pie-shaped sectors from cylindrical dielectric resonator antennas. The most-compact design (in terms of wavelengths) was a top-loaded cylindrical dielectric resonator antenna resonant at 820 MHz, with a diameter of $0.067\lambda_0$, and a height of $0.052\lambda_0$. More-compact designs should be possible by using a combination of metal loading and high dielectric substrates. Although this will come at the expense of a reduction in bandwidth, it may find use in narrowband applications. These dimensions can be further reduced if the designer is willing to sacrifice gain and bandwidth performance.

VII. Wide band Designs

For Various type of Radar applications which operates over wide frequency bands and thus require broadband antenna. In this review the acquired bandwidth of DRA's of simple shapes is first examine, before being presenting various techniques for the enhancement of the bandwidth.
As the bandwidth of the DRA's is inversely proportional to the dielectric constant, DRA's can be easily achieving a wideband performance by keeping Ɛr very low. By analyzing model to predict the radiation quality of both circular and rectangular DRA's for keeping Ɛr=10, for rectangular DRA would be achieved a bandwidth about 20% and cylindrical DRA would between 30-40%for lowest mode orders without including the loading effects. The rectangular DRA's would achieve bandwidth 25% or more by operating in two or more different modes. The compact size and wideband performance is achieved by these simple DRA's also Provide advantage over resonant antenna. A majority of the designs use DRA's with Ɛr~10, and the maximum dimension are on the order of a half wavelength at the center of frequency band.

VIII. Summary

This survey article has highlighted the advancement of dielectric resonator antennas from an application point of view. The novel perspective intention of this survey work is to show a path for the betterment of modern sophisticated technical world with the proposed application oriented DRA models as well as to encourage the researchers for further miniaturization of the existing structures. This article perhaps works as a thrust for current antenna designers to find out the gap before introducing a new model. From this surveying process, it is clear that the dielectric resonator antenna has touched several applications starting from commercial day-to-day life up to important defense needs. This article outlined a common idea of the extreme use of DRA for microwave and technology based applications with afficient number of millimeter wave and specific frequency based applications. As per the current trend and status of application-oriented dielectric resonator antennas, the prediction of a wide control of modern communication systems in near future by DR-antennas cannot be ignored. Other than that DRA's comes with a known fact that the satellite communication, radar communication, mobile (PCS) communication, and biomedical communication are very much demandable area of wireless communication in the 21st century. The flexibility of using DR-antennas in those dedicated key areas can be considered as the milestones in DRAs research history. In a future perspective point of view the recommendations are as follows: (i) The use of flexible type of DRAs for biomedical, which could be a favorable directive for future researchers.
(ii) Characterization of DRAs for demandable communication links like: satellite, radar, mobile, etc., could be further enhanced.
(iii) In view of modern compact communication devices the miniaturization of the existing ones would be much valuable.

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Although it is tried to level best to outline all the important and novel contribution of the DRA researchers for real field application based DRAs modeling across the globe, still the authors apologize to the researcher community if any important and novel contribution is skipped unknowingly and unintentionally during this survey process.

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