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Review of DRA Based Micro Strip Antenna Design and its Performance Parameters Evaluation

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Abstract– Present scenario of communication, all wired ones becoming wireless. So, to achieve efficient and affordable communication in wireless technology, compact and efficient radiators required. One of the efficient radiators is dielectric resonator antenna (DRA). Almost all the applied power will be lost in the radiated fields only, with this attractive feature DRAs become much popular in wireless communication field at microwave frequencies. In this project, new type of compact DRAs is designed for popular wireless applications of L, S, C and higher band application. This project covers the design of DRA which including all parametric studies of the return loss, radiation patterns, gain and directivity for specific wireless application. DRAs became very popular in the core sectors of a country like defense, military, radar and especially for millimeter wave applications.

Keyword- DRA, MATLAB And VSWR, Gain.

I. INTRODUCTION

Communications are becoming as a part of day-to-day life of human beings. So, to achieve efficient and affordable wireless communications, compact and efficient radiators required. Indeed, one of the efficient radiators is dielectric resonator antenna (DRA). The dielectric resonator antenna efficiently radiates at microwave frequencies. DRA is economically affordable and it is having desirable features like - easy design, simple fabrication methods and gives flexibility in design and to analyze the results in order to achieve required resonant frequencies depending upon our coverage requirements.

In general DRA having high-radiation efficiency, bandwidth and polarization flexibility make them by far superior and better replacement to conventional microstrip patch antennas (MPA). DRAs are intrinsically immune to those surface wave power leakage and conductor loss problems, which plagues the MPA and reduces their efficiency. DRA consists of high dielectric constant materials, high quality factors and mounted on a grounded dielectric substrate of lower permittivity [1]. DRA is fabricated from low-loss and high relative dielectric constant material of various shapes whose resonant frequencies are functions of the shape, dimensions of the shape and permittivity of the material. DRA can be in a few geometries including cylindrical, rectangular, spherical, half-split cylindrical, disk, and hemispherical shaped [1]. The DRAs have properties such as very less phase noise, small size, stability in frequency and temperature, ease of integration with existing technologies and other hybrid MIC circuitries, flexible construction and the ability to withstand harsh environments. The DRA has some interesting characteristics, like small size, ease of fabrication, high radiation efficiency, increased bandwidth and low production cost. DRAs are very promising for applications in wireless communications with high efficiency. Wireless communications have grown at a very rapid pace across the world over the last few years, which provide a great flexibility in the communication infrastructure of environments such as hospitals, factories, and large office buildings [2]. Dielectric Resonator Antennas (DRA)'s became very popular in the core sectors of a country like defence, military, radar and especially for satellite and millimetre wave applications. The resonating frequencies of a DRA are nothing but the function of size, shape and dielectric constants only.

Due to this flexibility in DRAs, they can be designed with different shapes as per coverage requirements depending upon the applications in the wireless communication industries. For many years, the dielectric resonator (DR) has primarily been used in microwave circuits, such as oscillators and filters, where the DR is normally made of high- permittivity material, with dielectric constant. The unloaded Q-factor is usually between 50 and 500, but can be as high as 10,000. Because of these traditional applications, the DR was usually treated as an energy storage device rather than as a radiator. The DRAs are good replacement for the Microstrip antenna, because the DRA has a much wider impedance bandwidth and higher power handling capability due to their many advantageous and attractive features. As such, these include their flexibility in design, light weight, compact size, the versatility in their shape and feeding mechanism, simple structures, easy fabrication and wide impedance-bandwidth.

In this thesis we have selected Cylindrical DRA. The main advantages of the cylindrical DRA consist in the ease of fabrication and the ability to excite different modes. The resonant frequency of the fundamental mode decreases by increasing the dielectric constant of the DRA. This behavior is the most important characteristic of the DRA since it allows decreasing the size of the DRA by increasing its dielectric constant. It is to be noted that the impedance bandwidth is inversely proportional to the relative permittivity of the DR. Therefore, the use of materials with high dielectric constant can result in a narrowband antenna behavior. DRAs can be excited with different feeding methods, such as microstrip lines, dielectric image waveguide feeding, aperture coupling, probes, slots, and co-planar lines.

However we have used Probe Fed method. By optimizing length and position of the feeding probe, the input impedance of the DRA can be tuned and, consequently, the resonance frequency can be controlled. The main benefit associated with a probe penetrating the DRA is that it provides high coupling to the DR which, in turn, results in high radiation efficiency. To increase the sensitivity carbon Nano-tube is used. Nano- tubes have better conductivity than copper when scaled to their diameter. It has recently been that the dc resistance per unit length of a single-walled carbon nanotube at room temperature is about 6 kΩ/μm. A copper wire with the same diameter (1.5 nm) would have an even higher resistance per unit length. Young's modulus 1054 is better than steel 208.

Scope of this Project

The scope of this project work is to design and fabrication of a Dielectric Resonator Antenna which can be used for wide-band specific wireless applications according to the Federal communication commission specifications. That is used the operating frequencies like L, S,C etc and the antenna should be small in size and easy-to-manufacture with available laboratory equipment. The return loss must be less than -10 dBi at wireless frequencies, which means only 10% of power will be reflected back while 90% of power is transmitted. Other aspects, such as beam width, side lobes, VSWR, Polarization, Impedance measurements were also considered during the design stage. Special attention had paid in design stage to get the double bands at a time by optimizing the feeding techniques and structures of the dielectric resonators.

II.PROBLEM STATEMENT

Ideally we have to design microwave antenna which serve like an isotropic antenna, whereas an isotropic antenna is a point source that radiates equally in all directions. They have no losses, 100% gain, 100% efficient, very high impedance bandwidth, no conduction losses, high flexibility and versatility more over perfect impedance matching meets the requirement of many wireless applications and data communications.

Solution to the Challenges

DRAs have been extensively used for numerous applications since they have many attractive characteristics such as low profile, light weight, low cost, and inherently wide bandwidth. They could be used for numerous applications as both individual elements and in an array environment. In addition, wide bandwidth, low cost, low dissipation loss at high frequency, and high radiation efficiency are the inherent advantages of DRAs over conventional patch antennas. Compared with Microstrip antennas, which suffer from higher conduction loss and surface waves in antenna array applications, DRAs have high radiation efficiency and high power handling capability due to lack of metallic loss.

Unlike the microstrip antenna, DRA does not support surface waves if placed on a ground plane directly. In recent years, DRAs have been considered as potential antennas for mobile phone applications. A general problem in the miniaturization of RF resonators used in filters and small antennas is decrease of efficiency, due to conductor losses. In DRAs, lower conductor losses, compared to those in typical metal antennas such as microstrip patches can be expected because DRAs have fewer metal parts. Thus, DRAs are good potential alternatives, especially when very small antenna elements are needed. In addition, they can be easily incorporated into microwave integrated circuits because they can be fabricated directly on the printed circuit board (PCB) of the phone. Specific features of DRAs have made them suitable for a variety of applications specially MMW applications. DRAs have small size and low cost. They can be easily coupled to almost all types of transmission lines [3],[4,5].

DRA have several advantages compared to conventional microwave antennas, and therefore many applications cover the broad frequency range. Some of the principal advantages of dielectric resonator antennas compared to conventional microstrip antennas are:

- DRA has a much wide impendence bandwidth than microstrip antenna because it radiates through the whole antenna surface except ground port while microstrip antenna radiate only through two narrow radiation slots.
- Higher efficiency.
- Avoidance of surface waves is another attractive advantage of DRAs over microstrip antennas
- However, dielectric resonator antennas have some advantages:
- Light weight, low volume, and low profile configuration, which can be made conformal;
- DRA has high degree of flexibility and versatility, allowing for designs to suit a wide range of physical or

electrical requirements of varied communication applications.
- Easy of fabrication
- High radiation efficiency
- High dielectric strength and higher power handling capacity
- In DRA, various shapes of resonators can be used (rectangular, cylindrical, hemispherical, etc.) that allow flexibility in design.
- Low production cost.
- Several feeding mechanisms can be used (probes, slots, microstrip lines, dielectric image guides, and coplanar waveguide lines) to efficiently excite DRAs, making them amenable to integration with various existing technologies [1], [3], [6] -[7,8].

III. RADIATION PATTERN

The basic term "radiation" means that, the distribution of power through respective fields of antenna. An antenna radiation pattern or antenna pattern is defined as "A mathematical function or a graphical representation of radiation properties of the antenna as a function of space coordinates". However, in most cases the radiation pattern is determined in the far field region and is represented as function of directional coordinates. The properties of Radiation are power flux density, radiation intensity, field strength, directivity phase or polarization. The radiation properties of most concern are the two or three dimensional spatial distribution of radiated energy as function of the observer's position along a path or surface of constant radius. A trace of received power at constant radius is called power pattern. On the other hand, a graph of spatial variation of the electric (or magnetic) field along constant radius is called amplitude field pattern. In practice the dimensional pattern is measured and recorded in series of two dimensional patterns [4].

IV.LITERATURE SURVEY

Pandey Rajat Girjashankar et al. [1] A rectangular dielectric resonator based connected ground quad- elements MIMO antenna fed usin substrate integrated waveguide (SIW) is proposed for millimeter-wave 5G application. SIW in TM10 mode was used to excite multiple modes in the dielectric resonator to achieve multiple resonance. An individual element of the proposed MIMO antenna is arranged in a cross shaped structure to achieve polarization and spatial diversity. The proposed MIMO system operates at dual operating frequency bands having impedance bandwidth of 24% (24.50–27.50 GHz) and 12% (33–37 GHz). The isolation better than 22 dB and 17 dB is achieved throughout the proposed bands without using any additional isolation techniques. The proposed MIMO antenna has a peak gain of 9.9 dB and minimum radiation efficiency of 96%. It radiates in a broadside direction with acceptable MIMO diversity results where envelope correlation coefficient is below 0.15, channel capacity loss is below 0.6 bits/sec/Hz, diversity gain of 9.98 dB, and total active reflection coefficient below −10 dB over the desired band of operation. The prototype of the quad-elements SIW fed DRA MIMO was manufactured after which the antenna and diversity performance parameters were measured and satisfactory correlation is observed.

Simei Zhai et al. [2] Low temperature sintered $Li_8Mg_xTi_3O_{9+x}F_2$ microwave dielectric ceramics with x = 2−7 were developed based on a newly designed pseudo ternary phase diagram of the Li_2TiO_3–MgO–LiF system. Dense solid solution ceramics (of relative density >96 %) with cubic rock-salt structure, accompanied by a small amount of secondary phase MgO, were obtained in the temperature range of 800−925 °C. With increasing Mg^{2+} content, the value of ε_r decreased, whereas that of τ_f remained nearly constant, and the Q × f increased to a maximum at x = 5. The good compatibility with Ag electrodes highlights the promising prospects of this ceramic in low-temperature co-fired ceramic technology. Furthermore, a dielectric resonator antenna fabricated based on a $Li_8Mg_5Ti_3O_{14}F_2$ ceramic exhibited an outstanding S_{11} of −34.7 dB and a broad bandwidth of 360 MHz at the desired resonant frequency of 5.98 GHz.

M. Haydoura et al. In this paper, ferroelectric ceramics with $(Sr_2Ta_2O_7)_{100-x}$ $(La_2Ti_2O_7)_x$ (STLTO) compositions have been investigated and their dielectric properties have been characterized in wide frequency band (from few kHz to few GHz); their integration in Dielectric Resonator Antennas (DRA) was conducted. The dense STLTO ceramics have been obtained by high temperature sintering of powders synthetized by solid state chemistry route. STLTO crystalline cell parameters and volume vary linearly as a function of the chemical composition (x) thus demonstrating an ideal solid solution domain for $0 \leq x \leq 3$.

Dielectric characterizations highlight that the permittivity and the dielectric loss vary according to the composition (x) and that the lowest losses are obtained for x<1.65 compositions. The latter corresponds to the transition between the ferroelectric and paraelectric compositions of the STLTO material at room temperature. A low profile DRA structure was realized using a cylindrical paraelectric STLTO resonator (with x = 0) with a permittivity of 83 and losses tanδ = 5 × 10^{-3}@3.3 GHz. The DRA prototype was simulated, produced and tested. It exhibits a hybrid $HEM_{11\delta}$ mode, with a resonant frequency at 5.80 GHz, a 4.9% bandwidth and a gain of 6.4 dB. These features confirm the potential of the paraelectric STLTO compositions in compact antennas radiating at frequencies below 6 GHz [3].

Manpreet Kaur et al.[4] This paper presents a compact pattern reconfigurable antenna for sub-6 GHz (4.8 GHz-5 GHz) applications. The proposed antenna consists of a quarter- wavelength radiator with two circular slot-loaded oval-shaped patches on both sides of the radiator. The antenna's ground plane is loaded with an inverted L-shaped structure. Two PIN diodes are used to switch the direction of radiation. Good agreement between simulated and measured results is obtained. The −10 dB impedance bandwidth of the proposed design is 370 MHz. The peak gain is 5.5dBi, and efficiency is 82 % in different diode states. The proposed antenna is then analyzed with the Nordic nRF9160 DK board to check the design reliability.

Yu Jiang et al.[5] Garnet-typed ceramics of Y3Mg1-xMnxAl3SiO12 ($0 \leq x \leq 0.2$) have been synthesized using the traditional solid-state reaction method. The optimal microwave dielectric properties ($\varepsilon r = 10.73$, $Q\times f = 62{,}824$ GHz, $\tau f = -34.8$ ppm/°C) are obtained for Y3Mg0.9Mn0.1Al3SiO12 (x = 0.1) sintered at 1575 °C for 5h. A millimeter-wave dielectric resonator antenna is designed and fabricated using Y3Mg0.9Mn0.1Al3SiO12 as a dielectric unit due to its excellent characteristics of low dielectric constant and high $Q\times f$. The designed DRA resonates at 24.94 GHz with a bandwidth ∼2.20 GHz (S11 < −10 dB). The simulated gain and efficiency are 6.64 dBi and 91.08%, respectively. The results indicate that the Y3Mg0.9Mn0.1Al3SiO12 ceramic has a potential application as an antenna for the 5G/6G millimeter wave frequency band.

Gourab Das et al.[6] In this article, an eight-element, sixteen port dielectric resonator (DR) based double sided multi-port antenna is presented, which supports the unique dual-directional pattern diversity feature. The orientation of the double-sided dielectric resonator antenna (DRA) is one of the novel features of the proposed antenna. Four cylindrical dielectric resonator antennas (cDRAs) are placed at the top of the substrate, and each top cDRA is excited with the help of two orthogonally placed coplanar waveguide (CPW) fed conformal microstrip lines. In the same manner, the other four cDRAs are placed at the bottom of the substrate, and each cDRA is fed via conformal strip lines.

Mahdi NoroozOliaei et al.[7] The absorption of light is very important task for retina photoreceptors. Graphene is an energy harvesting material and one of the best models for the electromagnetic wave absorption and its conversion into signals. In this paper, an electromagnetic modeling of human retinal photoreceptors has been presented based on graphene coated material as a receiver antenna. The proposed electromagnetic model based on dielectric resonator antenna (DRA) is being analyzed for retina photoreceptors of human eye (cones and rods) by Finite Integral Method (FIM) collaborated with CST MWS. The results show that the model is good for vision spectrum with a proper field enhancement in cone photoreceptor due to its sensitivity to light.

P Soni Reddy et al.[8] In this paper, a simple technique to enhance the polarization purity in a square dielectric resonator antenna (SDRA) using metal strip loading on the probe feed is presented for point-to-point communication applications. Coaxial feed placed at the commonly used offset location adjacent to the DRA has been studied in this regard. Cross polarized (XP) fields scattered from the feed into the air are found to be one of the reasons behind the deterioration of polarization purity in SDRA. When a thin metal strip is loaded on the probe feed using liquid solder to control these XP fields, the measured result shows an XP isolation of 47 dB at the boresight, 42 dB and 29 dB at the angular region of ±30°in the E-plane and H-plane, respectively. The proposed technique helps to overcome many unavoidable fabrication errors associated with complex machining and drilling processes involved in contemporary DRA designs for XP suppression. The proposed SDRA design offering good XP isolation performance and simple fabrication technique is highly suitable for low cost and high precision applications.

Harshavardhan Singh et al.[9] This paper presents a simple method to design 3D on-chip antenna with improved gain and efficiency. In the proposed method, without introducing any additional metal-based ground layer, a low resistive Si substrate is used as the ground plane for a monopole fed dielectric resonator antenna (DRA). A cylindrical DRA (CDRA) made-up of Barium Titanate BaTiO3 is placed on the top side of the oxide coated Si wafer and is excited under TM011 mode with a coaxial probe inserted from the bottom of the substrate using TSV (through silicon via) hole.

Monika Chauhan et al.[10] A low profile circularly polarized high directive Dielectric Resonator Antenna (DRA) is presented for X - band wireless applications. DRA is excited by microstrip aperture slot coupling which is employed on the bottom side of the substrate. Two asymmetric rectangular split rings are created adjacent to the feed line on the substrate to enhance the 3- dB axial ratio bandwidth and impedance bandwidth. Corrugated circular ring shaped single layer double sided meta superstrate is loaded on the DRA to enhance the peak gain to 11.9 dBi. The extracted lumped element model of the Superstrate unit is found to be in concurrence with Electromagnetic (EM) simulations. The proposed geometry offers a 1.1 GHz axial ratio bandwidth with 2.6 GHz impedance bandwidth. A prototype is fabricated and experimentally verified.

V.PROBLEM IDENTIFICATION

1) Narrow Bandwidth for Electrically thin substrates
2) High frequencies Results in,
a) More ohmic losses
b) Electrically thicker substrates which support surface waves and decrease radiation efficiency.
3) Low gain
4) Poor polarization purity
5) Spurious feed radiation
6) MPA having low dielectric strength, hence they cannot handle as much output power as other antennas

VI.MOTIVATION

Dielectric resonator antennas (DRA) possess some attractive characteristics which are making them as very promising and affordable at microwave frequencies for wireless applications. Wireless Communications are becoming part in day-to-day life of public. So, to achieve efficient wireless communications, efficient radiators required. Definitely, one of the promising radiators is nothing but dielectric resonator antenna (DRA). The dielectric resonator antenna efficiently radiates at millimetre- wave frequencies. DRA is economically affordable. DRA has desirable features like - easy design, simple fabrication methods and gives flexibility in design and to analyze the results in order to achieve required resonant frequencies depending upon our coverage requirements. Dielectric Resonator Antennas (DRAs) are usually ceramic resonators that radiate energy into space when excited appropriately. The microwaves are confined inside the resonator material by the abrupt change in permittivity

at the surface, and bounce back and forth between the sides. For a given resonant frequency, the size of the dielectric resonator is inversely proportional to the relative permittivity of the constitutive material. The basic principle of operation of dielectric resonators is similar to that of the cavity resonators. The most two popular radiating dielectric resonators are the cylindrical and the rectangular ones. The interests in such antennas are due to its prospect of shrinking down the sizes of antennas for satellite phone operations and its potential in reducing the cost and ease of manufacturing. DRAs are one of the most recent progresses in antenna technology, taking its place on par among the more common antennas, such as wire, microstrip, horn, and reflector antennas. DRA has the inherent merit of having no metallic loss. This merit is especially good for high frequency applications where conductor loss is proportional to the frequency. DRAs also offer easy coupling schemes to transmission lines by simply varying the position of the feed points. And there is much room for flexibility in design to optimize for bandwidth.

On the manufacturing side, the DRA can be easily tuned to its resonant frequency by using a tuning screw attached above the DRA. The large degree of freedom means that design is difficult because a lot of variables interplay with each other. However, if the physics is well understood, it is possible to design the DRA to operate at nearly any rational input impedance, thus eliminating the need of a matching circuit. The complexity of the DRA can be exploited.
Objective

The aim in this synopsis is to design a Dielectric Resonator Antenna (DRA) for microwave frequency based ultra wide band (UWB) applications. The research work undertaken is a rectangular shaped DRA is selected to overwhelmed the narrow bandwidth and high conductive losses of conventional microstrip patch antennas. An anisotropic material is chosen as dielectric material with dielectric constant expressed by a tensor. The designed antenna have the dimensions of 30mm 20mm 10mm. Using HFSS software the simulation results obtained as resonant frequency at 4.6 GHz within a bandpass frequency range. Results are cross verified by matlab simulation of characteristic equation for oscillation frequency for cavity resonator. Time independent Helmholtz wave equations for unperturbed and perturbed model of dielectric cavity resonator is formulated and analyzed. Delta change in resonant frequency is calculated. Which validate that applying perturbation method to calculate resonant frequency is correct.

VII.CONCLUSION

The research work in this thesis includes two major aspects related to the dielectric resonator antennas (DRAs): The first part of the thesis describes multifunction and diversity DRA implemented using a single dielectric resonator (DR), while the second part of the thesis extends DRA research from microwave to the visible spectrum. These two aspects are respectively based on two attractive features of DRAs,

- Various resonant modes can exist in a DR volume and each mode is related to different radiation characteristics. The orthogonality of field distribution for the fundamental modes builds the basis for realization of low coupling multi-mode design. The resonance frequency and bandwidth of selected orthogonal modes can be designed to satisfy the desired requirements by optimizing the DR geometry and the configuration of the feeding network.
- The high radiation efficiency of DRA has been experimentally proved in the millimeter wave (MMW) frequency region due to the absence of the inherent conductor losses in DR. This motivates further scaling towards optical frequencies, and suggests favorable performance when compared to metallic optical antennas. Apart from these two features, other

advantages of DRAs, including small size, light weight, low cost, coupling to most transmission lines and design flexibility, allow for a wide range of designs to satisfy specified requirements.

In light of these features, various DRAs have been proposed in the literature with enhanced performance in terms of bandwidth, gain, radiation efficiency and functionality. It is noted that a deep and thoughtful understanding of resonance frequency, excited modes, and impedance bandwidth and radiation characteristics is generally required to create novel advanced designs. As basis for this understanding, the canonical DRA geometries, including hemisphere, rectangle and cylinder, are the fundamental building blocks for all other advanced DRA geometries.

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