Survey Paper on Circularly Dielectric Resonator Antenna for Satellite Communication

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Abstract— The proposed technique is an integration of a slot antenna and a dielectric resonator antenna (DRA). This is designed without compromising miniaturisation and efficiency. It is observed that the integration of slot and dielectric structure itself may be merged to achieve extremely wide bandwidth over which the antenna polarisation and radiation pattern are preserved. Here the effect of slot size on the radiation performance of the DRA is studied. The antenna structure is simulated using the HFSS software. The simulated results are presented and compared with the measured result. This DRA has a gain of 7.1 and 6.3 dBi at 5.7 and 8.1 GHz, respectively, its 10 dB return impedance bandwidth of nearly 4.5% and 5.5% at two resonating frequencies. A total of 98% efficiency has been achieved from the configuration. It is shown that the size of the slot can significantly affect the radiation properties of the DRA and there are good agreements between simulation and measured results.

Index Terms— Dielectric Resonator Antenna, Micro strip Antenna, Circular.

I. INTRODUCTION

Probably the most popular and commonly used antenna type of the current decade is the microstrip patch antenna. The popularity of the microstrip patch antennas may have been fuelled by the development of the low cost manufacturing techniques of microstrip antennas. The popularity may also be attributed to the availability of the standard quality substrates for the manufacture of high frequency antennas. This may be evident from the fact that even though microstrip patch antennas were first reported in the decade of 1950 [1] it took about two decades to attract researchers to this field. Also, the development of a particular technology is basically need oriented. As it is said "necessity is the mother of invention" the need for special type of antenna for communication to be used within missile systems and in handheld communication devices have found the solution with microstrip antennas. This has resulted in tremendous research and development in the field of microstrip patch antennas in the last decade which led to the implementation of the antennas in the end-devices [2]. Over the ages it has also been observed that one technological development is dependent on the development of the others. Here, in case of mobile communication, the practical usability of the mobile system was dependent on the size of the mobile handsets. The size of these devices was also dependent on the size of the antenna being used among other components. Previously these devices used to have large sized antenna which had to be mounted on large objects [3]. Hence these were not truly handheld. But with the advent of Microstrip Patch Antennas (MPA) among other developments, the size of the mobile communication devices have changed drastically.

Microstrip patch antennas are low cost, low profile, light weight, high frequency planar antenna. It is a derivative of microstrip circuits. Microstrip patch antenna consists of a dielectric layer sandwiched between two very thin metal layers. One of the layer acts as the radiating layer while the other acts as the ground plane. Generally, the thickness of the dielectric layer of the MPA is very small compared to the size of the antenna. Hence it is also conformal to the surface. Since MPA are derivative of microstrip circuits, they have good compatibility. A microstrip patch antenna also finds application in many devices other than personal communication devices. It may have been used in the missile system, airborne AESA radar, body worn antenna for military personal etc. The applications are endless [4].

The main component of wireless communication is antenna for transmitting/ receiving the radio waves. Now a days, as the size of mobile devices reduces day by day so we have to design low profile antennas. For this purpose mainly two antennas were developed namely microstrip antenna and dielectric resonator antenna. Microstrip antennas having several advantages like light weight, low cost etc. But the main disadvantages of microstrip antenna are its narrow bandwidth, high metallic losses and surface wave loss [5]. To overcome the drawback of microstrip antenna, dielectric resonator antenna has been developed.

The dielectric resonator is usually made of high permittivity lossless dielectric material normally with a dielectric constant greater than 20. They are the energy storage devices. Dielectric resonators are usually surrounded by metallic plate in order to prevent radiation [6]. If the metallic plate is removed, a dielectric resonator radiates the energy and then it works as an antenna. Radiation from open DRs was first time implemented by Richtmyer in 1939. There are lots of advantages of DRA such as low metallic losses and also avoid surface waves due to which we get higher efficiency. Another important feature of DRA is that it gives higher bandwidth as compared to microstrip antenna [7].

II. LITERATURE REVIEW

Shahin Salarian et al. [1], microstrip patch antennas have been modeled and investigated at Ka-Band frequencies, to achieve high gain for satellite communications application. Structures of one, two, three and four elements arrays have been designed, modelled and simulated numerically using MATLAB and CST software at 29 GHz. Different configurations have been tested to find the optimum structure in terms of Gain, input impedance matching, phase matching and spacing between arrays. Various feeding techniques have been tested to find the optimum feed network, which is a combination of series and corporate feed. A gain of 12dB was achieved using the structure of four element arrays with beamwidth of 38 degrees.

Antennas are very important component in wireless communication system. There are different types of antennas exit practically which we used for transmit and receive EM waves. Out of these microstrip antenna is one of the most important antenna nowadays due to their attractive features such as low profile, light weight, low cost and ease in fabrication.

Yao-Dong et al. [2], a new single-fed wide dual-band circularly polarized (CP) dielectric resonator antenna (DRA) is presented in this letter. The DRA is excited by a microstrip line through the narrow underneath rectangular aperture, and its HE_{111} and $HE_{11\delta}$ (2 <; δ <; 3) modes are utilized for the dual-band design. To achieve CP fields, two notches are truncated from the cylindrical DRA at φ = 45° and 225 °. A pair of equal arc-shaped slots is used to improve the axial-ratio (AR) and impedance bandwidths. The antenna features impedance bandwidths (|S_{11}| <; -10 dB) of 26.25% and 11.17%, and 3-dB AR bandwidths of 15.8% and 5.02% in the lower and upper bands, respectively. To verify the simulation, the antenna is designed and measured. Reasonable agreement between measured and simulated results is obtained.

Halappa Gajera et al. [3], a technique of dielectric perturbation in a dielectric resonator antenna (DRA) have been explored with specific application to filter out higher resonating modes causing unwanted radiations. This is especially conceived and conjectured for microstrip fed cylindrical DRA (CDRA). Creating a protruded cavity in it filled with dielectric material of varying εr is the primary mechanism. Effect of such perturbation has been experimentally demonstrated establishing air ($\varepsilon_r = 1$) as the simplest and most promising one for a specific application in weakening $HEM_{21\delta}$ mode in it, recently identified as the source of cross-polar radiations. Physical insight into this new technique is also clarified. As much as 10 dB reduction in the principal plane cross-polarized values without affecting the primary radiations has been documented.

Debatosh et al. [4], Microstrip patches and dielectric resonators (DRs) are two low-profile variants of modern microwave and wireless antennas. However, the DR antenna (DRA) is relatively new and still passing through the stages of development. Both variants are quite similar in terms of performance and characteristics. This article focuses on a meaningful comparative study where we have considered all commonly used feed mechanisms such as coaxial probe, microstrip line, and rectangular aperture for both antennas operating near the same frequency. Circular geometry, i.e., cylindrical DRA (CDRA) and circular microstrip patch antenna (CMPA), have been chosen, and a systematic investigation based on thorough experiments has been executed. Multiple sets of prototypes have been fabricated and measured at 4 GHz. All available data have been furnished and compared, indicating relative advantages and disadvantages. This comparative study should provide qualitative and quantitative instructions to a designer for choosing the right element and corresponding feed based on design requirement and feasibility.

Debatosh et al. [5], in this communication, cross-polarized (XP) radiation of cylindrical dielectric resonator antenna (CDRA) has been investigated with a view to identify the source of the same. The study starts with a conjecture, which has been established through a systematic study using simulated results. The inference has been verified experimentally with the help of a set of prototypes. $HEM_{21\delta}$ has been identified as the XP generating mode and a small metallic grounded post of circular cross section has been conceived to perturb the same to prove the conjecture. This insight has been extended to demonstrate a practical application indicating a possibility of achieving up to 8-10-dB suppression in XP radiation from a CDRA.

Awab Fakih et al. [6], a new low profile and broadband monopolar patch antenna is proposed. Previously, long rectangular patch antennas were proposed that had a compact structure and high gain, but these antennas were designed for broadside radiation. There are some patch antennas that achieve wide bandwidth by employing a thicker substrate. However, its profile may not be low enough for some cases that cover a very low profile space. We propose a low profile patch antenna with wide bandwidth, high gain and monopole like radiation pattern. The proposed antenna has a bandwidth of 9.4% and gain of 7 dBi with monopole like radiation pattern for an infinite ground plane. While for a finite ground plane bandwidth of 12.3% and gain of 5 dBi is obtained.

Vikas Gupta et al. [7], in this paper a slot has been loaded in square patch antenna which was resonating originally at three different frequency bands viz. 7GHz, 10GHz and 13GHz. The loading of the slot results in the suppression of higher frequency bands and reduction in resonant frequency of original square patch antenna. Reduction in the resonant frequency results in the reduction in the size of patch antenna. The slot loaded patch resonates at 5GHz and the simulation results indicate the return loss at 5GHz is-33.75dBi, VSWR is 1 and gain is 6.2dBi. The paper compares the parameters of original and slotted patch antenna. The IE3D electromagnetic simulation and optimization engine based on MoM has been used for the purpose.

III. PROBLEM FORMULATION

Due to rapid growth in wireless communication, the research on low profile, multiband and dual polarized antennas are extremely focused. Different types of antennas are available to fulfill all these requirements, such as microstrip antenna, slot antenna, and dielectric resonator antenna (DRA). Out of these antennas, DRA is one of the most noticeable radiators due to its integral potentials such as no metallic loss and high radiation efficiency [1]. In order to develop multiband characteristics in DRA, several techniques have been developed such as higher order mode generation (HEM_{111} and HEM_{113} mode) in cylinder-shaped DRA [2]. Different shapes of DRA have also been studied to obtain multiband characteristics such as pentagon, stair rectangular DRA [3, 4]. There are various higher order modes such as $HE_{21\delta}$ mode which is quite easily generated in CDRA due to its low quality factor. These modes are not advantageous in the case of antenna because it affects the radiation characteristics of other fundamental modes. Similarly, it is not easy to generate higher order modes (which is useful in the case of antenna) with the help of a simple feed structure [5, 6]. In order to avoid these difficulties, the concept of hybrid DRA comes into existence, which represents combination of DRA with other resonating structures [7, 8]. Similarly, Khalily et al. presented a hybrid CDRA (split half CDRA with fork shape monopole) for multiband applications [9]. Cylindrical DRA along with parasitic slots on ground plane was proposed by Sharma and Gangwar. Recently, dual-polarized antennas are the most favorable topic of the researchers due to their several advantages such as orientation insensitive, getting more information by radar from targets, etc.

IV. METHODOLOGY

Dielectric constant of the substrate gives mechanical strength to the microstrip patch antenna. In order to predict the resonant frequency, resonant resistance and other antenna parameter, the propagation constant for a wave in the microstrip substrate must be accurately known. This can be done by accurately estimating the dielectric constant of the substrate materials, and the temperature tolerance of the permittivity.

There is no one ideal substrate; the choice rather depends on the application. Substrate choice and evaluation is an essential part of the design procedure. Many substrate properties may be involved in these considerations; dielectric constant and loss tangent and their variation with temperature and frequency, thermal coefficient and temperature range. Low frequency application requires high dielectric constants to keep the size small. For high power application of microstrip patch antenna, a thick cladding is desirable. Microstrip patch antennas used low dielectric substrates.

In this project, we have used RT duroid 5880 substrate with dielectric constant 2.5 and this substrate has following features

- High thermal conductivity
- Low loss tangent
- Thermally stable low profile and reverse treated copper foil
- Advanced filler system

USB Microstrip Antenna

In the recent rapid research of ultra-wideband (UWB) technology, the UWB antenna is one of the most essential components for an UWB system. Many applications such as local network, imaging radar, and communication employ UWB technology. Therefore, developments of UWB antennas become important and complex for system and antenna designers. In conventional UWB systems, the antenna radiates in the preferred direction with high gain performance and operates over a broad impedance-matched bandwidth. One of the examples would be log-periodic antennas; they have broadband impedance matching and reasonable gain in the desired direction. However, due to their dispersive properties on broadband waveform radiation, extra compensations and complexities are required. Another type of broadband antenna would be the TEM horn.

To have lower dispersive rating, bi-conical antennas are a good choice for broadband systems. Bi-conical antennas have a broadband impedance match and tend to generate non-dispersive waveforms. However, when applying UWB systems to portable devices, conventional UWB antennas are not suitable. This is mainly due to their bulky size and directional properties. Monopole and dipole antennas are good options for portable UWB devices. They have great features such as broadband impedance matching, small size and omni-directional radiation. However, from a system design point of view, fabrication may not be easy because those antennas require a perpendicular ground plane.

Therefore, planar or printed-circuit board (PCB) antennas are much more suitable in terms of manufacturing complexities. Also, when designing UWB antennas, designers must make new considerations based on new UWB standards.

V. EXPECTED OUTCOME

The research objectives are given in the following:

Design and analysis of dual-band/multiband dielectric resonator antenna/antennas at frequencies used in the area of communication will be done:

- Through simulation software using Ansoft HFSS simulation software.

Through experimental investigation

- Fabrication of multiband and wideband dielectric resonator antenna/ antennas.
- Measurement of input characteristics and radiation pattern of the fabricated antennas.

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