A Review Paper on Dielectric Resonator Antenna for Wireless Applications

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Abstract- *This paper represents a study of simulation of a Dielectric Resonator Antenna (DRA) based on its Rectangular shape for wireless application. Various designs of Rectangular Dielectric Resonator Antenna are described in this paper. In this rapid changing world in wireless communication, Dielectric Resonator antenna has been playing a key role for wireless service requirements. Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (Wi-MAX) have been widely applied in mobile devices such as handheld computers and smart phones. The Dielectric Resonator Antenna for WLAN and Wi-MAX application with variety of substrate, feed techniques are presented in this paper. In this paper we also discuss the basics of Dielectric Resonator Antenna, various feeding techniques, design model and antenna parameters with their advantage and applications.*

Keywords- Dielectric Resonator Antenna, Return Loss, Gain, Directivity, Wi-MAX, WLAN, Feed techniques, CST Microwave Studio.

I. INTRODUCTION

The study on Dielectric Resonator Antenna has made a great progress in the recent years. Compared with the conventional antennas, Dielectric Resonator Antenna have more advantages and better prospects. In this era of next generation networks we require high data rate and size of devices are getting smaller day by day. In this evolution two important standards are Wi-Fi (WLAN) and Wi-MAX. For success of all these wireless applications we need efficient and small antenna as wireless is getting more and more important in our life. This being the case, portable antenna technology has grown along with mobile and cellular technologies.

Dielectric Resonator Antenna have characteristics like low cost and low profile which proves Dielectric Resonator Antenna to be well suited for WLAN/ Wi-MAX application systems. The field of wireless communications has been undergoing a revolutionary growth in the last decade.

In the last 2 decades, two classes of novel antennas have been investigated and extensively reported on. They are the microstrip patch antenna and the dielectric resonator antenna (DRA). Both are highly suitable for the development of modern wireless communications. The use of a dielectric resonator as a resonant antenna was proposed by Professor S. A. Long in the early 1980‟s. Since the Dielectric Resonator Antenna (DRA) has negligible metallic loss, it is highly efficient when operated at microwave and millimeter wave frequencies. Conversely, a high-permittivity or partially metallized dielectric resonator can be used as a small and low-profile antenna operated at lower microwave frequencies. Low loss dielectric materials are now easily available commercially at very low cost. This would attract more system engineers to choose dielectric resonator antennas when designing their wireless products.

In the last decade, a considerable attention has been focused on dielectric resonator antennas (DRAs) as an alternative to microstrip antenna. DRAs represent a relatively novel application of dielectric resonators (DRs). These resonators are unshielded and rely, for field confinement within their boundaries, on a very high difference between their own permittivity and the permittivity of the outer medium. The low-loss, high permittivity dielectrics used for DRs ($10 \leq \varepsilon r \leq 100$), ensure that most of the field remains within the resonator, so leading to high quality factor Q. If the permittivity constant is not too high and the excited mode presents strong fields at the resonator boundaries, the Q drops significantly inasmuch part of the stored energy is radiated in the environment. Since dielectric losses remain low and the size of the DR are small with respect to the free-space wavelength, these radiators provide small and high efficiency antennas.

DRAs are used in different applications as they exhibit several attractive features like small size, high radiation efficiency, light weight, simple structure, better performance when used in phased array configurations (since they can be packed more tightly). Furthermore, consisting of 3D structures, DRAs show more degrees of freedom for their geometrical definition and shape. Many studies on DRAs have been devoted to radiation efficiency, radiated field characteristics and to enlarge the impedance bandwidth, but less attention has been given to their harmonic tuning and hence to their use in active integrated antennas. Recently several contributions have been presented where harmonic tuning techniques have been proposed for C-band rectangular dielectric resonator antennas.

II. DIELECTRIC RESONATOR ANTENNA

The structure of DRA mainly consists of three basic components; they are first one Substrate, secondly ground (Perfect Electric Conductor) material etched on substrate and some dielectric resonating material placed above the ground, generally referred as "Dielectric Resonator (DR)".

- Basically DR is an electronic component that exhibits 'resonance' for a wide range of frequencies, generally in the microwave band.

- If the DR placed in an open environment, Power will be lost in the radiated fields only. This fact makes dielectric resonators useful as antenna elements instead of elements in microwave circuits as energy storage devices.

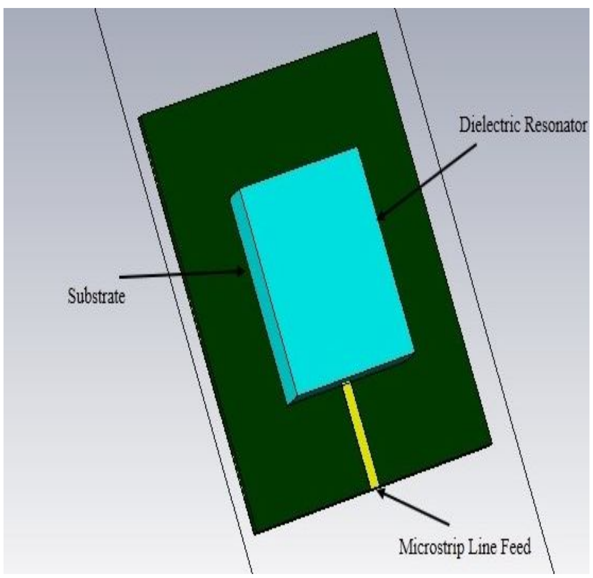

Figure 1. Rectangular Dielectric Resonator Antenna

Resonances can occur at the following frequencies

$$f_{mnp} = \frac{1}{2\sqrt{\varepsilon\mu}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}$$

Where ϵ is the permittivity, μ is the material permeability, and m, n and p are integers. The rectangular resonator with length a, breadth b and height d.

Dimensions of Dielectric Resonator can be calculated by the following equations:

$$k_x^{\,2} + k_y^{\,2} + k_z^{\,2} = \varepsilon_r k_0^{\,2}$$

$$k_z \tan\left(\frac{k_z d}{2}\right) \sqrt{\left((\varepsilon_r - 1) k_0^{\,2} - k_z^{\,2}\right)}$$

$$Q = \frac{2\omega W_e}{P_{rad}}$$

$$k_x = \frac{\Pi}{a}; k_y = \frac{\Pi}{b}; k_o = \frac{2\Pi f_o}{C}; C = 3\times10^8 m/S$$

Where kx, ky, and kz denote the wavenumbers along the x, y, and z directions, respectively, inside the DR.

Basic Characteristics of DRA

DRA offers several attractive features including the fallowing characteristics:

- In DRAs, we can use a wide range of dielectric constants (ε_r = 2.1 – 100), that allowing the designer to have control over the physical size of the DRA and its bandwidth.
- The Size of DRA is proportional to λ0/√ ε_r, where λ0 is the free space wavelength at the resonant frequency, and is the dielectric constant of the material.
- DRAs can be designed to operate over a wide range of frequencies from 1.3 GHz to 40 GHz.
- High radiation efficiency (95%) due to the absence of conductor or surface wave losses.
- Several feeding mechanisms can be used (including slots, probes, microstrip lines, dielectric image guide, and coplanar waveguide lines) to efficiently excite DRAs.
- DRA can be excited by several modes, many of which radiate pattern similar to short electric or magnetic dipoles, producing either broadside or Omni-directional radiation patterns for different coverage requirements.
- By choosing a dielectric material with low-loss characteristics, high-radiation efficiency can be maintained, even at millimeter-wave frequencies, due to an absence of surface waves and minimal conductor losses associated with the DRA.

Basic-shaped Dielectric Resonator Antenna

Three basic shapes of the DRA as Cylindrical, rectangular and hemispherical are the most commonly used. Here, we studied about different shapes of DRAs and their various field mode Configurations. These analyses can be used to predict the resonant frequency, radiation Q-factor, and radiation pattern of DRA

Figure 2. Various shapes of Dielectric Resonator Antenna

III. LITERATURE REVIEW

In (1), In this paper, the design of rectangular dielectric resonator antenna with coaxial probe and microstrip line feed arrangements and corresponding return loss vs. frequency characteristics and radiation performance in C-band of microwave frequencies using CST Microwave Studio. The simulation results obtained using the numerical methods for the probe and microstrip line feed DRA are compared on the basis of feed arrangements and the type of numerical method used. a return loss is obtained at a peaks whose value are -20dB at frequency of 5.8GHz & a directivity 2.83dBi & gain 2.7dB using microstrip line feed and return loss -19dB at frequency of 5.8GHz and a directivity 2.2dBi & gain 2.0dB using probe feed is obtained. The results of present work may provide design guidelines for the development of efficient DRA using coaxial probe and microstrip line as feeds.

In (2), In this paper, A DRA design is presented for WLAN applications. By using a DRA with an inverted U-shape cross section and optimized rectangular patch adhered in between the Dielectric resonator as a feeding mechanism, a high impedance bandwidth and covering a frequency range of 5-6GHz is achieved. A return loss is obtained at a peaks whose value are -22.7dB at frequency of 5.5GHz & a directivity 6.17dBi & gain 6dB. The proposed antenna is suitable for wireless local area networks application in 5-6GHz frequency range. This U shape Dielectric Resonator Antenna exceeds the bandwidth requirements for the IEEE 802.11a wireless local area networks application.

In (3), In this paper, the measurement results of the dielectric resonator antenna with High permittivity have been presented. With this technique, a high bandwidth (return loss < -10 dB) of center frequency at about 5-6 GHz for application in WLAN has successfully been achieved. The co-polarization radiation is strongest at $\theta \cong 00$ from the broadside in the E-plane. The cross-polarized patterns are about 10 dB less than the co-polarized patters in the broadside direction. The antenna has a 3 dB beam angle of about 1050 A return loss is obtained at a peaks whose value are -30dB & gain 5.9dB at frequency of 5.3GHz is obtained.

In (4), In this paper, dielectric resonator antenna operated at 3.5 GHz was design and simulated using CST Microwave Studio. Direct microstrip line feeding technique was used as the feeder. In this design, rectangular shape was used as the dielectric resonator as it offers more option to control the resonant frequency. The position of rectangular DR was varied to determine the best coupling and the distance was found to be 6 mm. Simulated return loss is -35.16 dB at frequency of 3.5GHz. It was found that rectangular DRA has potential to be used in wireless system.

In (5), This paper presents the comparison of different DRA antennas and the modes of coupling the energy to a DRA antenna to its ports. The DRA is excited by a conformal inverted-trapezoidal patch connected to a micro strip line. The wider bandwidth is achieved due to several factors such as rectangular shape of the dielectric resonator and feed mechanism. A return loss is obtained at a peaks whose value are -31dB at frequency of 5GHz & a directivity 5.5dBi & gain 5.7dB. The coupling mechanism has a significant impact on resonant frequency. An efficient bandwidth is achieved based on which antenna array structure is designed and the directivity increases largely. Various coupling methods have been described in this paper.

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.

IV. ANTENNA PARAMETERS

Different parameter such as VSWR, Return Loss, Antenna Gain, Directivity, Antenna Efficiency and Bandwidth is analyzed.

(a) Gain

The gain of an antenna is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. Formula for gain is $G=4\pi.U(\theta, \Phi)/Pin$, where, $U(\theta, \Phi)$ is an intensity in a given direction, Pin is input power.

(b) Radiation pattern

The radiation pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates.

(c) Antenna efficiency

It is a ratio of total power radiated by an antenna to the input power of an antenna.

(d) VSWR

Voltage standing wave ratio is defined as VSWR=Vmax/Vmin.It should lie between 1 and 2.

(e) Return loss

Return loss is the reflection of signal power from the insertion of a device in a transmission line. Hence the RL is a parameter similar to the VSWR to indicate how well the matching between the transmitter and antenna has taken place. The RL is given as by as:

$$RL=-20\log10(\Gamma)\ dB$$

For perfect matching between the transmitter and the antenna, $\Gamma = 0$ and $RL = \infty$ which means no power would be reflected back, whereas a $\Gamma = 1$ has a $RL = 0$ dB, which implies that all incident power is reflected. For practical applications, a VSWR of 2 is acceptable, since this corresponds to a RL of -9.54 Db.

V. FEEDING METHOD

There are several techniques available to feed or transmit electromagnetic energy to a dielectric resonator antenna. The five most popular feeding methods are the coaxial probe, slot aperture, microstrip line, co-planar coupling and dielectric image guide.

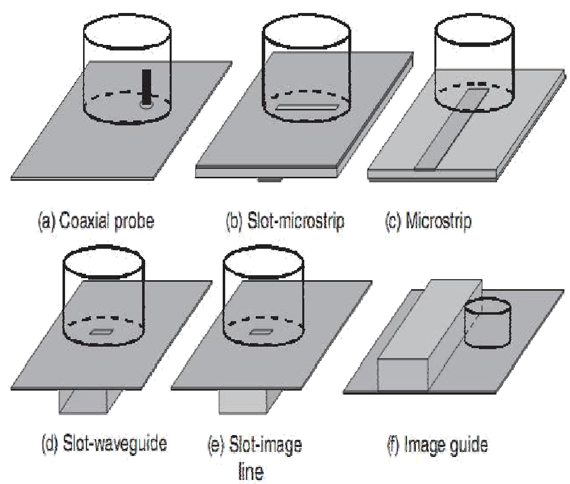

Figure3. Different excitation mechanisms for the DRA

VI. APPLICATIONS

1. Satellite communication, direct broadcast services.
2. Doppler and other radars.
3. Missiles and telemetry.
4. Mobile radio (pagers, telephones, man pack systems).
5. Biomedical radiators and intruder alarms.

VII. CONCLUSION

This paper presents the review on past done work in the field of Dielectric Resonator Antenna. After study of various research papers it concluded that by choosing proper structure for DRAs we can easily increase the bandwidth. The important techniques for improving the performance of DRA's as listed below.

- Optimizing the feeding mechanisms and the DRA parameters.
- Use of modified feed geometries (stub matching).
- Changing the shape of DRAs.
- Using Stacked Dielectric Resonators in DRA designs.
- Introduction of air gap between the ground and Dielectric Resonator.
- Changing the dielectric constant of Dielectric Resonator.

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