A Review Paper on Wideband Dielectric Resonator Antenna

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Abstract— DRA is an antenna that makes use of a radiating mode of a dielectric resonator. It consist of dielectric materials in its radiating patch also called as dielectric resonators (DRs) on one side of the substrate and has a ground plane (metal) on the other side. In the extreme demand of wireless communication technology it is the efficient radiators to achieve successful and affordable communication. DRA offers attractive features as antenna elements. These features include their mechanical simplicity, small size, high radiation efficiency due to no inherent conductor loss, relatively large bandwidth, versatility in the shape and simple coupling schemes to nearly all commonly used transmission line. This paper represents a study of a simple monopole antenna loaded with a cylindrical shape dielectric resonator as a wideband transmitting/receiving antenna for wireless applications and we also discuss the basics of Dielectric Resonator Antenna, various feeding techniques, design model and applications. Key words: Dielectric Resonator Antenna (DRA), monopole, wideband antenna

I. INTRODUCTION

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 \(\varepsilon_r > 20\). Because of these traditional applications, the DR was usually treated as an energy storage device rather than as a radiator. Although open DRs were found to radiate many years ago, the idea of using the DR as an antenna had not been widely accepted until the original paper on the cylindrical dielectric resonator antenna (DRA) was published in 1983. At that time, it was observed that the frequency range of interest for many systems had gradually progressed upward to the millimeter and near-millimeter range. At these frequencies, the conductor loss of metallic antennas becomes severe and the efficiency of the antennas is reduced significantly. Conversely, the only loss for a DRA is that due to the imperfect dielectric material, which can be very small in practice. After the cylindrical DRA had been studied, investigation of the rectangular and hemispherical DRAs was carried out. The work created the foundation for future investigations of the DRA.

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. But DRA has some additional advantages as compare to microstrip patch antenna like DRA has a much wide impedance bandwidth than microstrip antenna because it radiates through the whole antenna surface except ground part while microstrip antenna radiate only through two narrow radiation slots. It has higher efficiency. Avoidance of surface waves is another attractive advantage of DRAs over microstrip antenna.

In the last decade, attention has been focused on dielectric resonator antennas as an alternative to microstrip antenna. DRAs represent a relatively novel application of dielectric resonators. 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, 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 in as much 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. Furthermore, DRAs show more degrees of freedom for their geometrical definition and shape. It is a 3-dimensional device of any shape, e.g. rectangular, triangular, hemispherical, cylindrical, etc. figure 1 shows the various shapes of DRAs.

Fig. 1: DRAs of various shapes

As the future of wireless communication steers toward broadband and dual band applications the use of a basic monopole antenna is becoming less suitable. To meet the emerging broadband services, a monopole antenna must improve its bandwidth characteristic and provide the same level of simplicity while maintaining its omnidirectional pattern. A proposed new design involves the use of a monopole antenna loaded with an annular ring dielectric resonator antenna (DRA) operating in the TM 010 mode. In this arrangement both antennas produce a uniform horizontal coverage pattern.
II. WIDEBAND OPERATION

The hybrid monopole/dielectric resonator antenna (DRA) has become attractive to antenna designers due to its broadband characteristics along with the advantages of the DRA [1], [3]. Hybrid antenna consisting an annular dielectric resonator antenna combined with a quarter-wave monopole to simultaneously act as a radiator and a loading element, producing an ultra-wideband response. A prototype antenna is designed and a 3:1 bandwidth is demonstrated. The initial value of dielectric constant of DRA is 10. Return loss is better than -10dB for frequency 6 to 18.5GHz. Relating to the frequency bandwidth improves to 102.04% as a result. This antenna is able to achieve an ultra-wideband response by using HFSS simulation tool [1]. A very interesting work on the guidelines for the design of this antenna was presented [6].

A novel dielectric resonator antenna design is presented for wideband applications in H shape. By using a dielectric resonator with an optimized H-shaped across section and an optimized trapezoidal patch adhered on the concave surface of the resonator as a feeding mechanism, an impedance bandwidth of about 62% covering the frequency range of 3.61–6.85 GHz, is achieved [2].

In [3], a new four-element multilayer cylindrical DRA array is presented above the ground plane for wideband applications. The main objective of this is to improve the bandwidth of the DRA using HFSS tool. Parametric study was carried out. In this coaxial probe is used to excite multilayer cylindrical DRA. Different values of dielectric constant are used for each layer, so the effect of design parameters such as permittivity of materials, probe height and arrangement of dielectric are investigated. The proposed multilayer cylindrical dielectric resonator antenna can offer an impedance bandwidth 47% for return loss below -10 dB where frequency range is 4.06 to 6.07 GHz with monopole like radiation pattern which is stable in the passband with the gain of 4.73 dB at resonance frequency 4.3 GHz. This antenna is suitable for WiMAX application.

In [4], a simple, compact, wideband rectangular DRA is presented for bandwidth enhancement using a proper tapered strip excitation from one side of the DR. The radiation characteristics are improved by adding a shorted narrow strip to the opposite side of the excitation. By this short strip, further improvement in bandwidth is obtained.

Parametric study on strip dimensions is carried out. Dielectric constant used is 15. In this DRA offers good radiation characteristics and bandwidth of 96% between 2.13 and 6.08 GHz for VSWR <2 with gain 3 dB and also maintain return loss below -10 dB. This antenna is suitable for WiMAX. In [5], presents the use of rectangular DRA of low permittivity with dielectric constant of 9.4 and the modified T-shaped feed network includes a 50 ohm micro strip line to achieve strong coupling and for enhancement of bandwidth. The antenna performance was simulated over a frequency 3.1 to 5.5 GHz at the reflection coefficient better than -10dB. 55.8% relative impedance bandwidth, corresponding to 2.4 GHz obtained. The antenna exhibit 2.3dB gain at 3.1GHz. This small quasi omni directional dielectric resonator antenna has been proposed for the lower UWB, which is suitable for WiMAX applications.

III. ANTENNA CONFIGURATION

Antenna configuration of DRA mainly consists of three basic components; they are Substrate, ground/Perfect Electric Conductor material etched on substrate and dielectric resonating material mounted above the ground, referred as “Dielectric Resonator “. Generally in the microwave band, DR is an electronic component that exhibits ‘resonance’ for a wide range of frequencies. 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.

Fig. 1 shows the hybrid antenna geometry, consisting of a thin monopole and cylindrical DRA, both sharing the same axial reference, and mounted on a finite ground plane. Coaxial probe is used to excite the antenna. In this arrangement, the quarter-wave monopole is designed to resonate at the lower end of the frequency band while the DRA is designed to have a resonance near the upper end of the required spectrum. By properly choosing the dimensions of the DRA, the total bandwidth response of the quarter-wave monopole and DRA arrangement become much greater than the sum of the bandwidths of the individual antennas.

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

A. Frequency of Operation:
We would specify the Lower end and higher end resonances as \( f_L \) and \( f_H \) so that the effective impedance bandwidth can be obtained slightly larger on either side. The relation between \( f_L \) and \( f_H \) is formulate as:

\[
f_H = 2.5 f_L
\]

B. Dimensions of the Monopole (l and r )

\[
\text{Length (l): } l = \frac{\lambda}{4}
\]

C. DRA Parameters (a, b, h, \( \varepsilon_r \))

The spacing \( s \) between monopole and inner boundary of the DRA plays a significant role to develop higher end resonances and it is found to give optimum response when

\[
0.016\lambda_L \geq s \geq 0.013\lambda_L
\]
b is the inner radius of DRA, a is the outer radius of DRA, h is the height of DRA and \( \varepsilon_r \) is the permittivity of the material.

\[
\begin{align*}
b &= r + s \\
a &= b/0.3 \\
0.5A &\geq h \geq 0.4\lambda \\
\end{align*}
\]

Finally, the dielectric constant of the DRA material to be determined as follow:

\[
\sqrt{\varepsilon_r} = \frac{c}{2\pi f_h} \pi \sqrt{\left(\frac{2r^2}{a}\right)^2 + \left(\frac{2s}{2h}\right)^2}
\]

Where c is the velocity of light in free space.

IV. EXCITATION TECHNIQUES TO DRA

There are several techniques available to feed electromagnetic energy to a dielectric resonator antenna. The most popular feeding methods are the coaxial probe, slot aperture, microstrip line, co-planar coupling and dielectric image guide. The feeding network is kept below the ground plane which gives the advantage of avoiding spurious radiation. Moreover, slot aperture is widely used for integrating the dielectric resonator with the printed feed structure. The use of coplanar waveguides in exciting the dielectric resonator appears to be highly useful because they enable easy coupling with MMICs. This helps to adjust the coplanar level and the position of the dielectric resonator over the coplanar structure.

The dielectric image waveguide excitation method offers advantages over the microstrip line methods because it does not suffer from conductor losses even at millimeter wave frequencies. Usually the coupling is small between the dielectric resonator and the guide but it can be adjusted or increased by operating the guide closer to the cut off frequency.

In excitation through coaxial probe feed, the pin of the coaxial transmission line is extended through the ground plane. This acts as an electric current running vertically through the dielectric resonator antenna. The strength of the coupling depends on the length of the probe and different modes can be activated by changing the location of the probe, depending on what mode is desired. Another advantage of this method is that the antenna is directly connected to the circuit of \( 50 \Omega \) characteristic impedance without any matching network. The other method for excitation is the microstrip method which is the simplest method to activate the dielectric resonator antenna. The microstrip line is printed on the same substrate which is directly connected to the dielectric resonator antenna. By altering the permittivity of the substrate and by changing the distance to the dielectric resonator antenna, the level of the coupling can be adjusted. For wider bandwidth the permittivity should be kept low but this requires better coupling. Microstrips are easy to fabricate and it is also cost effective because the feedline is printed on the substrate but the disadvantage of microstrip is the limitation in polarization, as the polarization of an array is dedicated to the orientation of the microstrip line.

V. APPLICATIONS

These are the applications of Dielectric Resonator Antenna:
- WIMAX
- Mobile radio (pagers, telephones, man pack systems)
- Satellite communication
- Direct broadcast services
- Missiles and telemetry
- Biomedical radiators
- Doppler and other radars.

VI. CONCLUSION

This paper presents the review on past done work in the field of Dielectric Resonator Antenna. After study of various research papers it can be concluded that by choosing proper structure for DRAs and the feed mechanism, we can easily increase the bandwidth. By selecting the hybrid configuration of DRA with monopole we can even obtain a wider bandwidth as compare to DRA without monopole.

REFERENCES

