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WIDEBAND MONOPOLE/DIELECTRIC RESONATOR ANTENNA - A REVIEW

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ABSTRACT

Several wideband antennas are presented for either wireless application. This paper presents the performance of a simple monopole antenna loaded with an annular dielectric resonator as a wideband transmitting/receiving antenna. By adjusting the length of the monopole and load arm, a 10-dB bandwidth of 94% is achieved while maintaining monopole-like radiation pattern, which covers UWB application. The simulated result for return loss is verified with the measured data from a prototype antenna.

Keywords: Dielectric Resonator Antenna (DRA), Monopole, Wideband Antennas.

I. INTRODUCTION

Since 1970's, dielectric resonators (DR) have led to miniaturizations of active and passive microwave components, such as oscillators and filters. In a shielded environment, the resonators build with DRs can reach the unloaded Q factor of 20,000 at frequencies between 2 and 20 GHz. The principle of dielectric resonator operations is understood by studying electromagnetic energy vector distributions on a dielectric resonator structure. In the past, DRs were usually treated as an energy storage device rather than as a radiator or antenna. When a dielectric resonator is not entirely enclosed by a conductive boundary, it can radiate and turns to be an antenna. Although DRs were found to radiate many years ago, the idea of using DR as an antenna was not widely accepted until the original paper on cylindrical dielectric resonator antenna (DRA) was published in 1983. Subsequently, there were numerous studies and researches on the various applications of the DRAs. In 2005, Lapierre *et al.* proposed a hybrid of a quarter-wave monopole antenna and an annular dielectric resonator antenna to achieve wideband characteristics. This paper serves as an extension of the previous work the key considerations from the paper was the interaction between the dielectric and the monopole. The following sections will discuss on the pertinent points of the proposed paper and the improvement of the design using the two inner cavities. The DRA is an antenna that makes use of a radiating mode of a dielectric resonator (DR). It is a 3-dimensional device of any shape, e.g., hemispherical, cylindrical, rectangular, triangular etc. figure 1 shows the various shapes of DRAs [1].

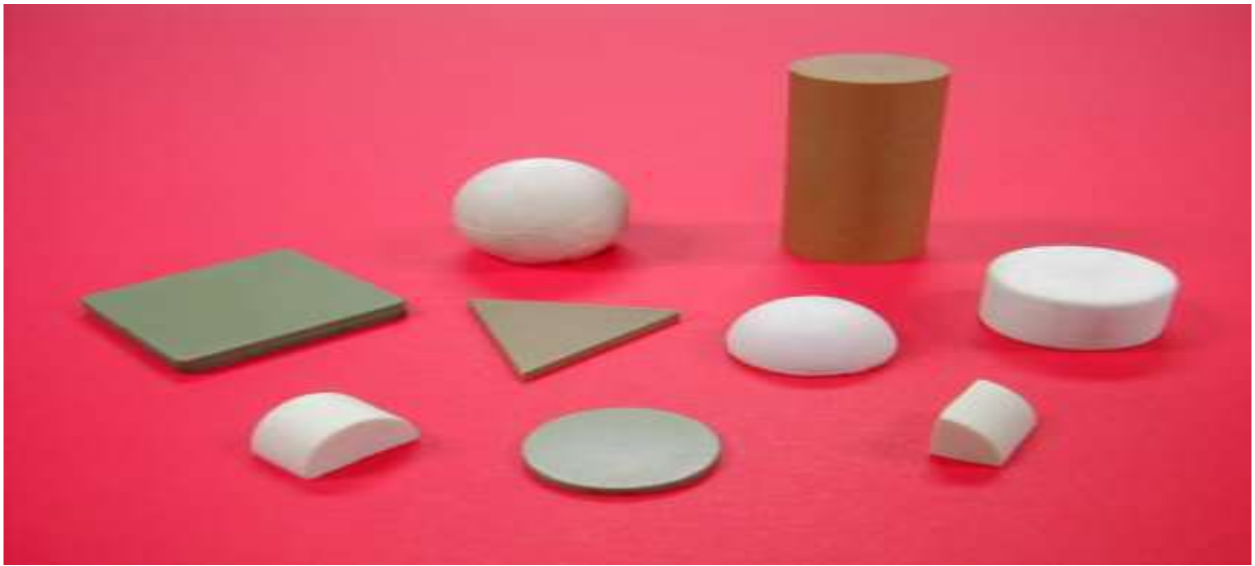

Figure 1. DRAs of various shapes [1]

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 **0**1δ mode. In this arrangement both antennas produce a uniform horizontal coverage pattern [2].

II. WIDEBAND OPERATION

When a single shaped DRA operates in a fundamental mode, its bandwidth is typically below 10%. The research of the wideband DRA was first experimentally carried out in 1989 by Kishk, who stacked two different DRAs on the top of one another to obtain a dual resonance operation. Since then other wideband DRAs using stacking methods have been reported. Alternatively, coplanar parasitic DR elements were placed beside the DRA to achieve wideband operation were reported. Recently, various bandwidth enhancement techniques have been developed for DRAs, such as co-planar parasitic DRAs, stacked DRAs, and deformed DRAs. More recently, proposed a disc-ring DRA by combining one smaller cylindrical DR and one larger annular-ring DR concentrically together to achieve a 45% impedance bandwidth. In the above mentioned wideband techniques, most cases are devoted to producing broadside radiation patterns [3].

As cylindrical DRA, the initial value of dielectric constant of DRA is 10. Length of the monopole keep changing with the size and permittivity of the DRA and the size of the ground plane. The feeding technique being use is monopole and also change the monopole shape to get better bandwidth. Graph separates three parts of frequency versus S_{11} parameters. They are, first part is related to DRA permittivity, second part is define to E-field of DRA and third part specifies monopole length. With the accurate dimensions of the monopole and the annular DRA antenna is able to achieve a wideband response [4].

As hemispherical/conical DRA, the dielectric constant value is 10. Considering the operating bandwidth hybrid monopole DRAs explored in this communication are the most enhanced. Further research should be done to get a wide range of applications starting from wideband EM sensor to UWB communication. The feeding technique been used is monopole. The frequency range was 6.5GHz which changes to 23.5GHz. Bandwidth increases to 126% [5].

The design of rectangular DRA (Dielectric Resonator Antenna), initial value of dielectric constant of DRA is 9.2. For better bandwidth performance the probe feed stack DRA applied to techniques, the DRA has a wider bandwidth and a better impedance matching within the FCC (Federal Communications Commission) UWB band. In this paper frequency has been achieved to 11.6GHz from 3GHz. The coaxial technique has been used. The bandwidth is 117.80%. Dielectric constant is maintained 10. The hybrid DRA consists of three elements, quarter wave length monopole dielectric resonator antennas of dielectric constant and a rectangular parasitic element. Return loss frequency is 7.6 to 14.6GHz. Relating to the frequency bandwidth improves to 118.98% as a result. Two-segments compact dielectric resonator antenna for UWB applications [6].

III. EXCITATION TECHNIQUES TO DRA

The operational mode depends on the method of excitation of the dielectric resonator antenna. The coupling mechanisms significantly affect the resonant frequency and radiation *Q*-factor of a dielectric resonator antenna. There are many different techniques which have been used and adopted in the past. These include coaxial probe, aperture coupling with a microstrip feedline, aperture coupling with a coaxial feedline, waveguide coupling with a microstrip feedline, direct microstrip feedline, coplanar feed, soldered through probe, slot line, conformal strip and direct image guide. Some of the excitation methods are shown in Figure 2.

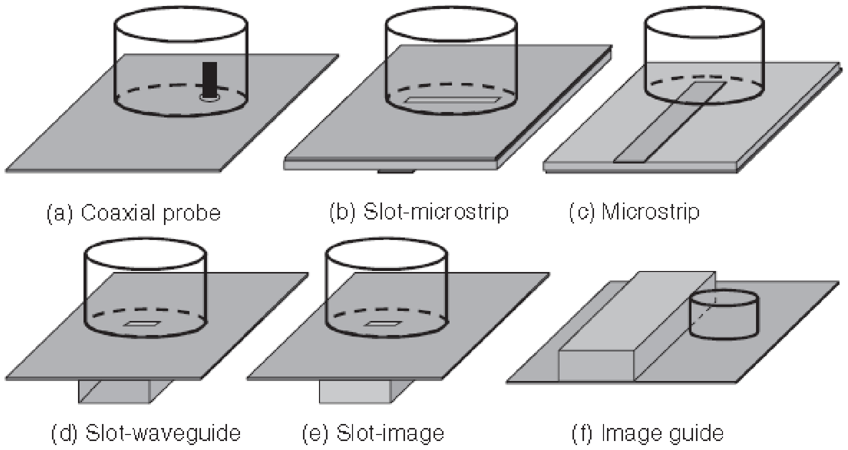

Figure 2. Different excitation methods for dielectric resonator antennas [1]

To couple to the aperture different shapes can be used such as a narrow slot, cross or C-shaped cut in the ground plane. These shapes can be fed by a microstrip line or a coaxial feedline beneath the aperture cut or the ground plane on the surface of the waveguide. In this way, the behaviour of the aperture is like a magnetic current which runs parallel to the length of the slot and excites the magnetic field of the dielectric resonator antenna. If the aperture size is adjusted or the dielectric resonator antenna is moved with respect to the aperture, the coupling level can be adjusted. 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. Impedance tuning can also be adjusted by adding a stub, slot, or loop at the end of the coplanar line, although the coplanar line and the coplanar loop work alike. In this way, the operational mode can be selected by changing the position of the dielectric resonator over the loop.

The dielectric image waveguide excitation method offers advantages over the microstip 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 cutoff frequency. This method is similar to the waveguide but this kind of excitations can be found in many applications, especially in series-fed linear dielectric resonator antenna arrays.

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 50Ω 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.

If both a coaxial probe and a microstrip line are used simultaneously, it gives the opportunity of exciting different modes simultaneously. By placing two microstrip lines near the antenna, two different modes can be excited [1].

IV. ANTENNA CONFIGURATION

Figure. 3 shows the antenna geometry, the antenna is a hybrid, consisting of a thin monopole and an annular DRA, both sharing the same axial reference, and mounted on a finite ground plane. 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. The two resonant frequencies are chosen so that a minimum return loss of 10 dB is maintained over the operating bandwidth.

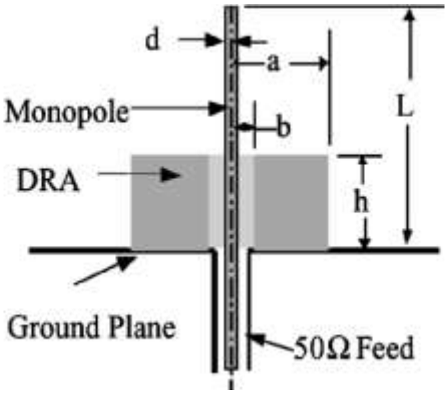

Figure 2. Cross section of the cylindrical monopole-DRA antenna [7]

V. SIMULATION RESULTS

There are a number of parameters that influence the general behaviour of this hybrid configuration; these include the length of the monopole, the size and permittivity of the DRA, and the size of the ground plane. The most critical in achieving the proper response was found to be the DRA aspect ratio h/a. For the selected $TM_{01\delta}$ resonance, this ratio controls the location of the loading effect, which in turn provides an impedance bandwidth bridge between the two resonators. Using Ansoft high frequency structure simulation (HFSS), shows the impact of using two different DRA heights to achieve a wide bandwidth response. Adjusting the height of the DRA significantly improves the mid-band impedance match, with no appreciable change in the monopole resonance frequency and only a small change in the DRA resonance.

A general design procedure for achieving broadband performance is as follows:

1) The resonant frequency of the DRA $TM_{01\delta}$ mode should be chosen approximately 2.2 times the resonance frequency of the calculated $\lambda/4$ monopole.
2) The height required to position the second resonance in the center of the bandwidth is a function of the permittivity of the material and the outer radius of the DRA. For a DRA of $\varepsilon_r = 10$, a ratio h/a of 1.0 is used as starting point.
3) A small air gap should exist between the monopole and the inner radius of the annular DRA. A spacing of about $\lambda_L/100$ (lower operating frequency) between the DRA and the monopole is sufficient. Any larger spacing will result in increasing the antenna size without any additional value.

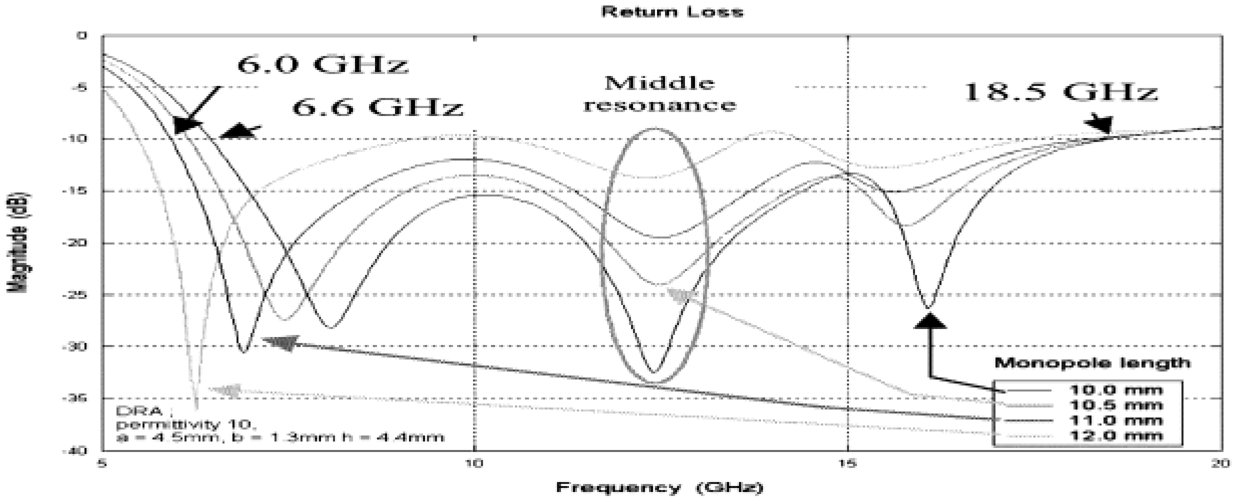

Figure 3. Return loss of the monopole DRA [7]

Using these guidelines as a starting point, the dimensions are adjusted to optimize the bandwidth response. The easiest parameter to adjust is the monopole length, for a fixed DRA design. Typical results are presented in Figure 3. It shows the return loss of the baseline DRA (b = 1.3 mm, a = 4.5 mm, h = 4.4 mm, ε_r = 10, ground plane radius 40 mm) coupled with monopole of different length. The simulations show that a -10 dB bandwidth.

VI. CONCLUSION

This paper presents the wideband performance of a hybrid antenna consisting of a thin monopole and an annular DRA as transmit and receive antenna. It can be concluded from this paper that the use of simple monopole has increased the operating bandwidth appreciably without making any major compromise in the performance in terms of cross-polarization pick up. Further work is underway in trying to design an ultra-wideband transmit and receive antenna system using simple monopole/DRA antenna.

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