Dielectric Resonator Antenna on Ba TiO$_3$ embedded with TiO$_2$ Nano composite for Wi-Fi applications

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Abstract. A cylindrical dielectric resonator antenna (DRA) energized using microstrip line for Wi-Fi applications is discussed in this paper. The cylindrical DRA of 14mm diameter and 2mm height are fabricated using titanium dioxide (TiO2) nanoparticle embedded in high dielectric constant barium titanate (BaTiO$_3$) material. It is found that the BaTiO$_3$: TiO$_2$ composite is very effective as a radiator. The fabricated DRA radiates in Wi-Fi frequency of 5.5 GHz with good reflection and radiation performance.

1. Introduction
Recently, dielectric resonators (DR) have become smart due to their precise advantages for some applications, including zero conductor loss and low profile. Dielectric resonator is usually made of low-loss high permittivity microwave dielectric materials [1]. It has been experimentally shown that DR can be an efficient radiator [2]. Many investigators reported experimental and theoretical estimations of Dielectric Resonator Antennas (DRAs) [2–9]. Though these presented results are applicable at high resonant frequencies, due to the resonant nature of the DRA’s, their bandwidth of operation is limited. This can be enhanced by decreasing the natural Q - factor of the resonant antenna. The Q - factor of the antenna can be reduced by decreasing the dielectric constant [9]. This is a simple solution. but it has drawbacks. This will lead to the larger antenna size, which will be hindrance in many Wi-Fi applications. For bandwidth enhancement, Fayad.H et al. have introduced stacked twin dielectric resonator [4] and Tadjalli.A et al. included the multilayer dielectric materials [9].

The ceramics are desirable for the applications in electronics sector and in a wide range of industrial application because of their inherent physical properties. Ceramic materials can be generally classified as poly-crystalline, non-metallic materials [10–12]. Barium titanate based ceramics are essential for several electrical devices, such as multilayer ceramic capacitors, lamp starters and thermistors, because of the ferroelectric behavior of barium titanate [13, 14]. A cylindrical dielectric resonator antenna (DRA) using barium titanate (BaTiO$_3$) having a dielectric constant and $\varepsilon_r = 1000$ was investigated by Ain et al. [3].

In this work a cylindrical DRA fabricated using Barium titanate embedded with Titanium dioxide nano composite for Wi-Fi applications is presented. Material is characterized by Scanning electron microscope. Antenna characterization is carried out using Vector Network
Analyzer and the results are presented in the following sections. Experimental results confirm that the antenna has a bandwidth of 590 MHz at 5.5 GHz with good radiation characteristics.

2. Materials and methods
Barium titanate having particle size <20µm is purchased from Ishu international. Titanium dioxide (Degussa P25) nanopowder used is of 25 nm in size. Polyvinyl Alcohol is of Ioba Chemie.

Preparation of BaTiO₃ with TiO₂ Nanocomposite: 0.5 g of Barium titanate and titanium dioxide are taken in 100:2 ratios and is mixed thoroughly. The composite is crushed for 1 hour and then add two drops of binder, which will bind the composite materials inside the pellet together. Binder is prepared by dissolving Poly-vinyl alcohol (PVA) polymer in water. It is prepared by adding 5% molecular weight (44.053 g/mol) of PVA in 1000 ml of water and stirred at 90°C for 3 hours. Two drops of binder are mixed with BaTiO₃ and TiO₂ powder and crushed for 15 minutes. Crushed powder is filled in a cylindrical die, 60 kg/cm² pressure is applied using hydraulic press then held it for 10 minutes. Then die is placed in an oven at 150°C for half an hour. Cylindrical pellets are removed from die. Pellets are placed in muffle furnace for sintering. Sintering is done in three stages, first started from room temperature, then gradually increase the temperature to 600°C and held it for 2 hours, after that increase the temperature to 750°C and held it for 2 hours and then increase the temperature to 900°C, held it for 3 hours and is allowed to cool slowly to room temperature. Cylindrical pellets of 14mm diameter and 2mm height are formed by this method and is used for further DRA studies.

3. Results and discussion

3.1. SEM Analysis of the DR
SEM images of different materials used in this work are shown in following figures 1 to 4.

![Figure 1. SEM image of BaTiO₃ Powder.](image1)

![Figure 2. SEM image of TiO₂ Powder.](image2)

Figure 1 shows the SEM images of BaTiO₃ powder which are micro in size. Nano TiO₂ powder is shown in figure 2. Since the TiO₂ powder is nano in structure, the enlarged volume of the sample is visible in this image. Figure 3 shows the SEM images of the pellet before sintering. It is seen from the image that the TiO₂ particles are visible inside the BaTiO₃ matrix. When it is sintered, all the TiO₂ particles grown inside the BaTiO₃ matrix completely and a compact structure is formed. It is evident from figure 4. Thus TiO₂ is completely embedded in side BaTiO₃ to form a uniform structure.
3.2. Analysis of DRA

Cylindrical dielectric resonator (DR) excited using a 50 Ω microstrip line (MSL) is shown in Fig. 5.

50 Ω line is etched on a material with dielectric constant of 4.5 and thickness of 1.6mm. The position of cylindrical DRA on the MSL is optimized for impedance matching. The antenna offers a 2:1 VSWR band width of 590 MHz (5.14 – 5.73 GHz) at 5.53 GHz as plotted in figure 6. The experimental set up is by using Keysight Vector Network Analyser to measure the reflection characteristics. This bandwidth is achieved with a peak gain of ~ 9 dBi with a gain better than 3.5 dBi in the entire bandwidth and is depicted in figure 7. Gain comparison method is used to measure the DRA gain in the anechoic chamber.
Figure 6. Reflection characteristics of the cylindrical DRA.

Figure 7. Measured Gain of the cylindrical DRA.

The radiation from the cylindrical DRA at the resonant frequency is as in figure 8. The radiation pattern in the two principal planes are measured and depicted in figure 9. The pattern shows a HPBW of 80° in H plane and 85° in E plane. The antenna characteristics is consolidated and presented in Table 1.

Figure 8. Radiation from the cylindrical DRA at 5.5 GHz.
Figure 9. Radiation Pattern of the cylindrical DRA at 5.53 GHz.

Table 1. Performance of cylindrical DRA

| Property               | Value       |
|------------------------|-------------|
| Resonant frequency (GHz) | 5.53        |
| Bandwidth (MHz)        | 590         |
| Peak Gain (dBi)        | 9           |
| HPBW                   | 85°/80°     |

4. Conclusion
This report illustrates a cylindrical DR – preparation, material characterisation and use of the resonator as an effective radiator. The DRA radiates in Wi-Fi frequency of 5.5 GHz with good reflection and radiation performance. A peak gain of 9 dBi with 590MHz of bandwidth is achieved experimentally for the antenna. In future different nano particles can be embedded to enhance the performance of the DRA.

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