The Bandwidth Enhancement of Dielectric Resonator Antennas.

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Abstract

In this work is reported an experimental and theoretical investigation on bandwidth enhancement of dielectric resonator antennas (DRA) using multiple DRAs, arranged according to the stacked configuration. Dielectric resonators antennas (DRAs) have been the subject of many investigations since they were introduced in 1982 by Long. Quite useful for high frequency applications, a dielectric resonator placed over a ground plane can serve as an effective radiator. Recent studies have demonstrated their potential for millimeter wave applications due to their several advantages over microstrip patch antennas such as high radiation efficiency, absence of surface waves and lower ohmic losses particularly at high frequencies. The antenna configuration consists of two cylindrical discs of different ceramic materials stacked vertically, one atop the other, placed above a ground plane, and excited by a coaxial probe. The lateral of the lower cylindrical DRA is placed against a coaxial probe, which excites the HEM\(_{11}\)\(_\delta\) mode. The numerical procedure is performed through a soft package based on the finite element method. Excellent agreement between theoretical and experimental is obtained. It is verified the concept of increasing the bandwidth of the dielectric resonator antenna by stacking two DRAs.

Introduction

Since they were introduced by Long et al. [1] in 1982, Dielectric Resonators Antennas (DRAs) have been the subject of many investigations. Recent studies have demonstrated their potential for millimeter wave applications due to their several advantages over microstrip patch antennas such as high radiation efficiency, absence of surface waves and lower ohmic losses particularly at high frequencies. Nevertheless, many characteristics of the DRA and microstrip antennas are common because both of them behave like resonant cavities [2, 3].

Generally, all resonant antennas will have a limited bandwidth of operation, due to their resonant nature [4]. Extensive research has been devoted to widening the bandwidths of DRAs by using several configurations [5]. In practice, multiple DRAs can be arranged in a pattern involving the stacking of cylindrical DRAs atop the other, in which the lower DRA is excited by a probe feed, while the upper DRA is electromagnetically coupled. This technique offers the advantage that each DRA can be individually tuned for either wideband or dual-band operation.

The geometrical scheme investigated here is that of comprising two cylindrical DRAs with different permittivity, and approximately the same dimensions, stacked one atop the other. This study is concerned with an experimental and theoretical investigation of the bandwidth enhancement by the stacking of cylindrical DRAs. The numerical procedure is performed through a soft package based on the finite element method.

Experimental Setup

The DRA stacked configuration implies on two (or more) cylindrical discs of different materials stacked vertically, one atop the other, placed above a ground plane, and excited by a coaxial probe, where the cylindrical DRA has radius \(a\), height \(h\), and relative dielectric permittivity \(\varepsilon\). The materials employed as DRAs were described in [6], and the values corresponding to their geometry and dielectric permittivity are: CRFO100 (\(a = \) \(R\)).
8.84, \( h = 9.2, \varepsilon_r = 8.37 \)); FCTO100 (\( a = 8.78, h = 8.37, \varepsilon_r = 13.25 \)). The experimental measurements were effected employing a network analyzer (HP 8716ET). A coaxial probe (gold) with length (L) equal 9 mm goes through the rectangular cooper ground plane with dimensions 355 mm x 300 mm and is connected to the network analyzer via SMA connector/coaxial cable. There are length compromises that need to be observed, because as the probe length increases the input resistance increases causing a strong tuning in the resonant frequency. Take account on the effect of the air-gaps is necessary for an improved numerical procedure. The simulations were conducted using Ansoft’s software High Frequency Structure Simulator (HFSS™), a soft package based on the Finite Element Method (FEM). An objective of this study is a numerical validation of the experimental setup. To run the program, the geometrical properties of the DRAs, together with their physical properties, were described. Several values were tested, and when the best results relating experimental and numerical procedures were attained, the simulation was finished. About the combination assemble of DRAs, in the first set of simulations, \( \varepsilon_{r1} \) and \( \varepsilon_{r2} \) were related to CRFO100 and FCTO100, respectively. Subsequently, the DRAs had their positions changed: \( \varepsilon_{r1} \) and \( \varepsilon_{r2} \) were related to FCTO100 and CRFO100, respectively. CRFO100/FCTO100 means CRFO100 above the ground plane and FCTO100 above CRFO100, for example.

Results and Discussions

It is showed in Fig. 1 the simulated and measured return losses of the coaxial feed cylindrical DRA. The mode with the lower resonant frequency is the fundamental broadside HEM_{11}. The matching frequency band for the coaxial feed DRA is from 3–5 GHz. Both simulated and measured results have a resonant mode at 3.52 GHz for CRFO100/FCTO100 and at 3.68 GHz for FCTO100/CRFO100, even below to the observed modes for the single DRAs (Fig 1). The sequence in which the materials are stacked also suggests the behavior observed, according to the coupling between the antennas elements. The computed results have been found to be in excellent agreement with experimental results. The considerations allied to the air-gap between the probe, resonator and the ground plane conducted in this study, were essential to the improvement of results through numerical procedure.

![Figure 1](image)

**Figure 1:** Experimental and theoretical return losses of single (CRFO100, FCTO100) and stacked DRAs (CRFO100/FCTO100, FCTO100/CRFO100).

Because of the highly resonant structure of the DRAs, the input impedance (Z), composed of a real (R) and imaginary (X) parts, at the feed presents a frequency response due to the resonant response of each mode.
Neglecting the overlap between the first and second modes, at the peak resonant resistance, the resistance ($R$) shows a maximum, as it could be seen in Fig. 2.

![Figure 2: Experimental and theoretical input impedance of single (CRFO100, FCTO100) and stacked DRAs (CRFO100/FCTO100, FCTO100/CRFO100).](image)

In summary, regarding to the 10 dB return loss bandwidth, it is observed an enhancement of this parameter after the stacking of DRAs. The bandwidth of the antenna is mainly influenced by the permittivity of the material. The DRA whose permittivity is 13.25 (FCTO100) has 10 dB bandwidth equal to 6.6%, and the DRA whose material permittivity is smaller, in order to 8.37 (CRFO100), has 10 dB bandwidth equal to 11.8%. Evidently in this study, as observed in [7], the bandwidth of the antenna decreases as the permittivity increases. The sequence stacking CRFO100/FCTO100 showed the best bandwidth enhancement, equal to 13.2%. The sequence stacking FCTO100/CRFO100 improved the 10 dB bandwidth of FCTO100, at CRFO100 expense.

**Conclusions**

Two cylindrical DRAs of the proposed materials arranged in a pattern involving their stacking one atop the other have been investigated in this study experimentally and numerically, taking advantage of the configuration of a monopole thorough an infinite ground plane, and using Ansoft High Frequency Structure Simulator (HFSS), respectively. Compared to the homogeneous DRAs, an enhancement of the bandwidth was obtained after their stacking, predominantly in the sequence CRFO100/FCTO100 (13.2%). Thus, it could be verified the concept of increasing the bandwidth of a stacked system of two distinct dielectric resonator antennas.

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