Application of a Dielectric Puck for a High Gain-Bandwidth Resonant Cavity Antenna

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***Abstract*—We propose a new type of resonant cavity antenna (RCA) that employs a small dielectric puck instead of the large dielectric superstrate layer used in the traditional RCA. The diameter of the puck is studied to determine its influence on the gain-bandwidth product (G·BW) of the RCA. Simulations of the waveguide-fed RCA demonstrate that the G·BW of the RCA with puck can be four times larger than that of the traditional RCA. Moreover, the antenna with puck is compact and can be easily fabricated, which makes it attractive for future high-frequency and very directive point-to-point communication links.**

I. Introduction

The gain of a primary radiator with a ground plane of perfect electric conductor (PEC) can be considerably enhanced by placing a partially reflective surface (PRS) in front of the radiator at a half-wavelength distance from the ground plane [1]. When a high-permittivity dielectric superstrate is employed as the PRS, maximum gain enhancement is achieved if the thickness of the superstrate is a quarter-wavelength and the material between the ground and the superstrate has low permittivity [2]-[3]. The complete structure is named a resonant cavity antenna (RCA).

The main disadvantage of the RCA is its narrow bandwidth of operation [1]-[3]. Recently, researchers used several techniques to enhance the bandwidth of the RCA, such as a tapered PRS [4], an array of radiators [5], a PRS of increasing reflection phase with frequency [6]-[7], and the reduction of the size of the RCA itself [8].

Here, we employ a dielectric puck in the place of the large superstrate of the traditional RCA to enhance its performance. As the diameter of the puck varies, both the gain and the bandwidth of the RCA vary as well, which alters the gain-bandwidth product (G·BW) of the antenna. We studied the performance of the antenna by using full-wave commercial numerical electromagnetics software. It will be shown that the G·BW of the RCA enhances from 1.52 (for the traditional RCA) to more than 7 for the RCA with an optimized puck diameter. Further, this RCA with optimized puck is compact.

II. Antenna Structure

For practical purposes, we assume commercially-available materials in this study. The design frequency is 14 GHz. Based on the availability of materials, we will use a puck of specific thickness and distance from the ground, that are close to the values calculated by following the design formulas for resonance in [1]-[3].

The top down and cross sectional views of the RCA under examination are shown in Fig. 1. A Ku-band rectangular waveguide feeds the antenna cavity through a 7.9 × 15.8 mm aperture located at the center of a square aluminum ground plate of side length *L*. A dielectric puck of high-permittivity low-loss Arlon AD1000 laminate (ε_r=10.2, tanδ=0.0023) that is 1.5 mm-thick and has a diameter *D* is suspended centered over the aperture and parallel to the aluminum plate by using a combination of low-permittivity low-loss foam materials (Rohacell IG-51; ε_r=1.057, tanδ=0.0017, and Rohacell IG-71; ε_r=1.115, tanδ=0.0017).

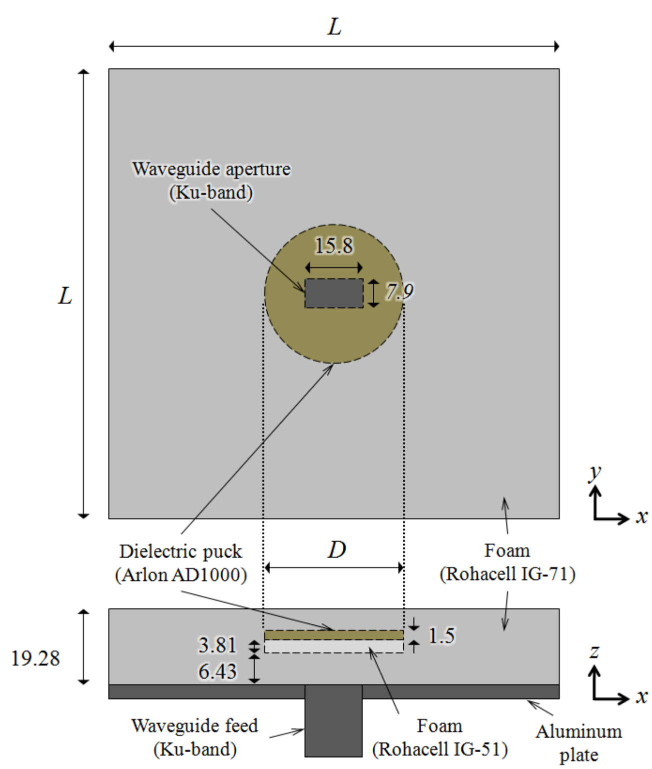

Figure 1. Top down (top) and cross sectional (bottom) views of the examined RCA. All dimensions are in mm.

III. SIZE STUDY OF THE PUCK

By using *CST Microwave Studio*, both the ground length L and the puck diameter D are varied and the radiation performance of the RCA is examined. Initially, L and D are set equal and are then increased gradually until the performance of the antenna is converged to a stable value. We found that the convergence is attained when $L = D = 10\lambda_0$ (where λ_0 = 21.4 mm is the wavelength in free space at 14 GHz).

Next, D is decreased gradually whereas L is maintained at $10\lambda_0$ in order to study the antenna performance as influenced by the puck size only. We found that the puck size affected both the gain in the broadside direction (+z axis) and also the fractional 3-dB bandwidth (the bandwidth of gain values less than 3 dB below the maximum value, divided by the center frequency of the band). Consequently, we will employ the G·BW (defined as the product of the maximum broadside gain (dimensionless) and the fractional 3-dB bandwidth) as the figure of merit.

The G·BW of the RCA versus the diameter of the puck is shown in Fig. 2 (solid line). The dashed line shows the G·BW level of the traditional RCA ($L = D = 25\lambda_0$). The G·BW is significantly enhanced when D is less than 5 wavelengths and reaches a maximum value of 7.18 when D is equal to $1.6\lambda_0$. This value is 4.7 times bigger than the G·BW of the traditional RCA (1.52).

Two immediate advantages of the optimized RCA with puck over the traditionally large RCA are perceived. First, the G·BW of the RCA with puck is much larger than that of the traditional RCA. Such large G·BW occurs with no reduction of either the gain or the bandwidth. For example, our optimized antenna has a maximum gain of 15.28 dB and bandwidth of 21.3%, whereas the very large RCA has a maximum gain of 13.29 dB and bandwidth of 7.13%.

Second, the RCA with puck is very compact. In fact, the ground length of the optimized antenna can be greatly reduced without affecting the performance of the optimized design, which results in a high-efficiency, easy-to-fabricate compact antenna.

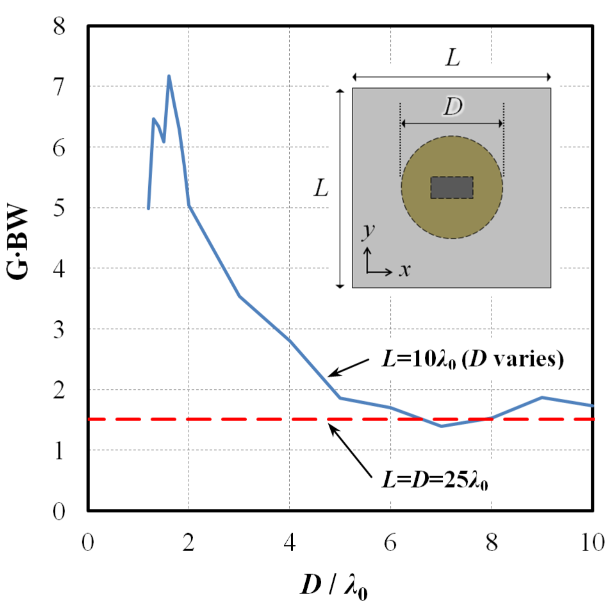

Figure 2. G·BW of the RCA constructed in Fig. 1 versus puck diameter (solid line) and G·BW of the traditional RCA (dashed line).

IV. CONCLUSION

We investigated the performance of a resonant cavity antenna with a dielectric puck of different diameters. It was shown that by changing only the diameter of the puck, the gain-bandwidth product of the antenna could reach values that are up to four times higher than that of the traditional antenna with a large superstrate.

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