Design and Analysis of Silicone Elastomer Based Broadband Dielectric Resonator Antenna (DRA) and its array

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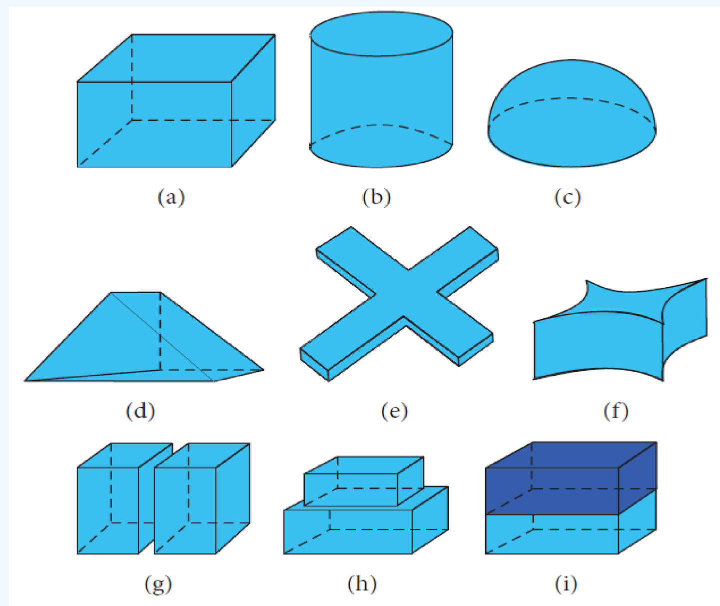
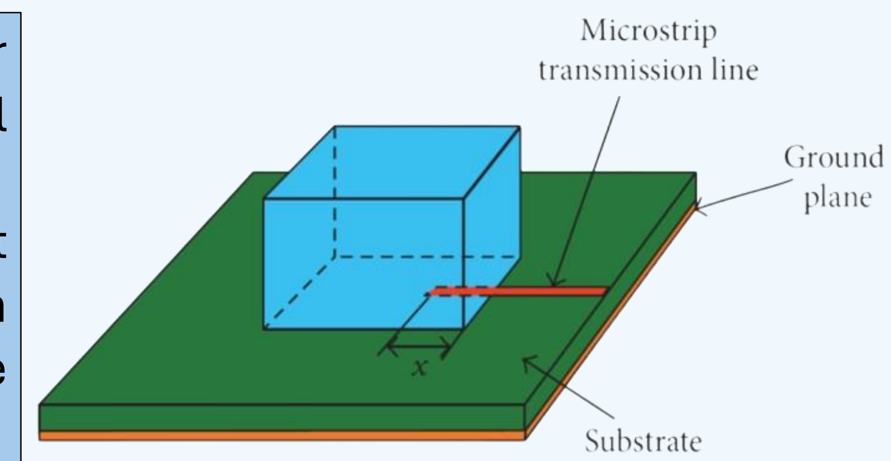
Introduction to Dielectric Resonator Antennas (DRAs)

- Uses a dielectric material resonator for radiation.
- High radiation efficiency, low conduction losses, wide bandwidth, compact size, compatible with MICs, able to obtain different radiation patterns using different modes.
- Various shapes to be chosen (cylindrical, spherical, rectangular, ...)



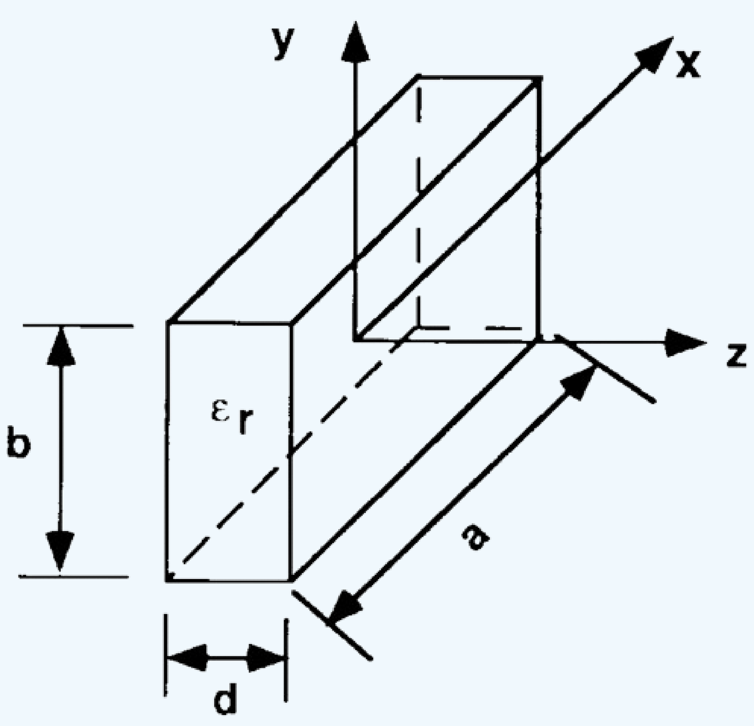
Choosing the Shape

- Rectangular DRAs (RDRAs) offer practical advantages over cylindrical and spherical shapes.
- The mode degeneracy (different modes with same f_c) is avoided in RDRAs by properly choosing the dimensions.



- RDRA provides more flexibility in terms of bandwidth control.
- The bandwidth of a RDRA increases with decrease in width and height.

Design Constraints

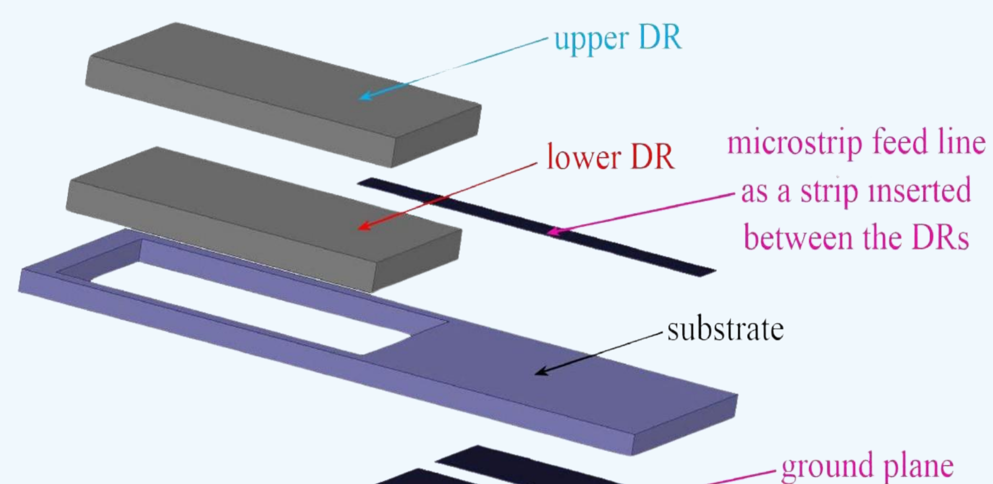


DRA dimensions are proportional to $\lambda_0/\sqrt{\varepsilon_r}$

Typically, DRAs have high ε_r of 20 and higher and operate at higher frequencies of 2-20 GHz. So, easy to obtain low-profile DRAs.

It's not the case here. Resonance frequency is medical ISM band (902 – 928 MHz (center of 915 MHz)), Silicone Elastomer of $\varepsilon_r = 2.5$.

Design Prototype



- To obtain a broadband DRA excited by a microstrip transmission line, a quite different type of design [2] is preferred.
- So, the ground plane does not cover the entire bottom surface and is partial.
- There are two DRs, not one, and the bottom one is inserted below the substrate for a certain length.

Solution Methodology

DWM equations for $TE^z_{mn\delta}$ mode.

$$k_x = \frac{m\pi}{a\ (width)} \quad k_y = \frac{n\pi}{b\ (length)} \quad (1)$$

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2 \quad (2)$$

$$k_z * \tan\left(\frac{k_z d}{2}\right) = \sqrt{(\varepsilon_r - 1)k_0^2 - k_z^2} \quad (3)$$

For given DRA parameters $\varepsilon_r, a, b, d, k_0$, DRA dimensions are the one where k_z calculated by (1) & (2), also satisfies (3). [2]

Evaluation and Optimization of the Solutions

Length determined by DWM turned out to be higher can be halved considering that this DR is placed on a substrate and metallic ground plane.

The dimensions along **y-axis (b)** and **z-axis (h)** shall be kept as small as possible to get higher bandwidth.

But **lowering b** results with extreme increase in **h** to satisfy the waveguide model equations. So, the first prototype of DRA dimensions are as follows:

$$a * \mathbf{b} * h = 6.75\ cm * \mathbf{7.5\ cm} * 3.36\ cm$$

Design Prototype on Simulation

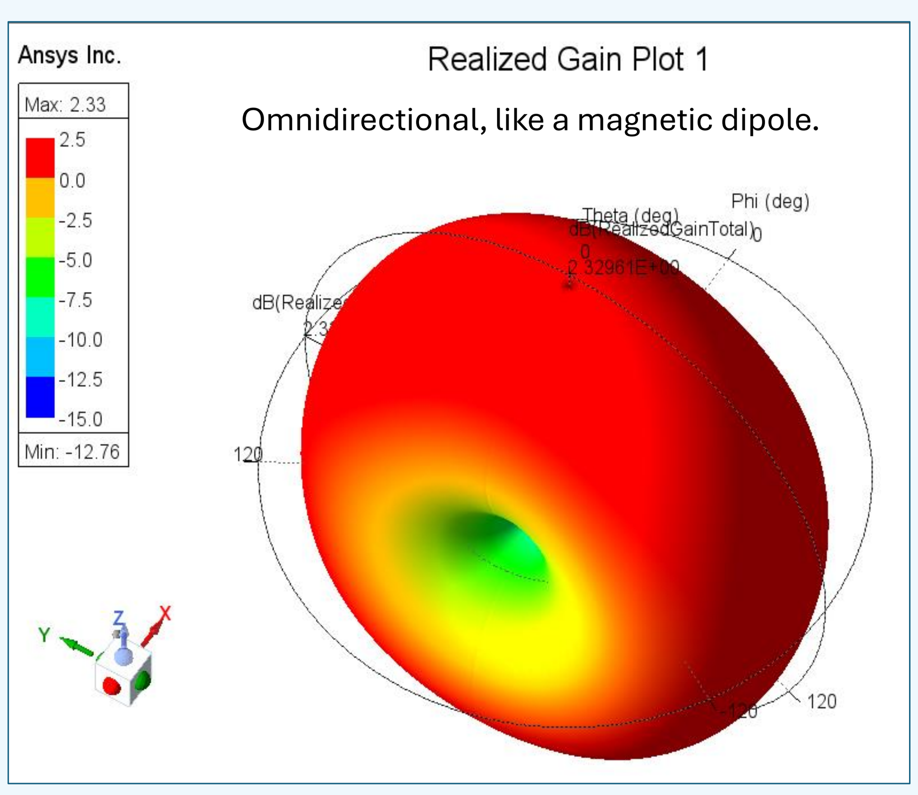
From bottom to the top,

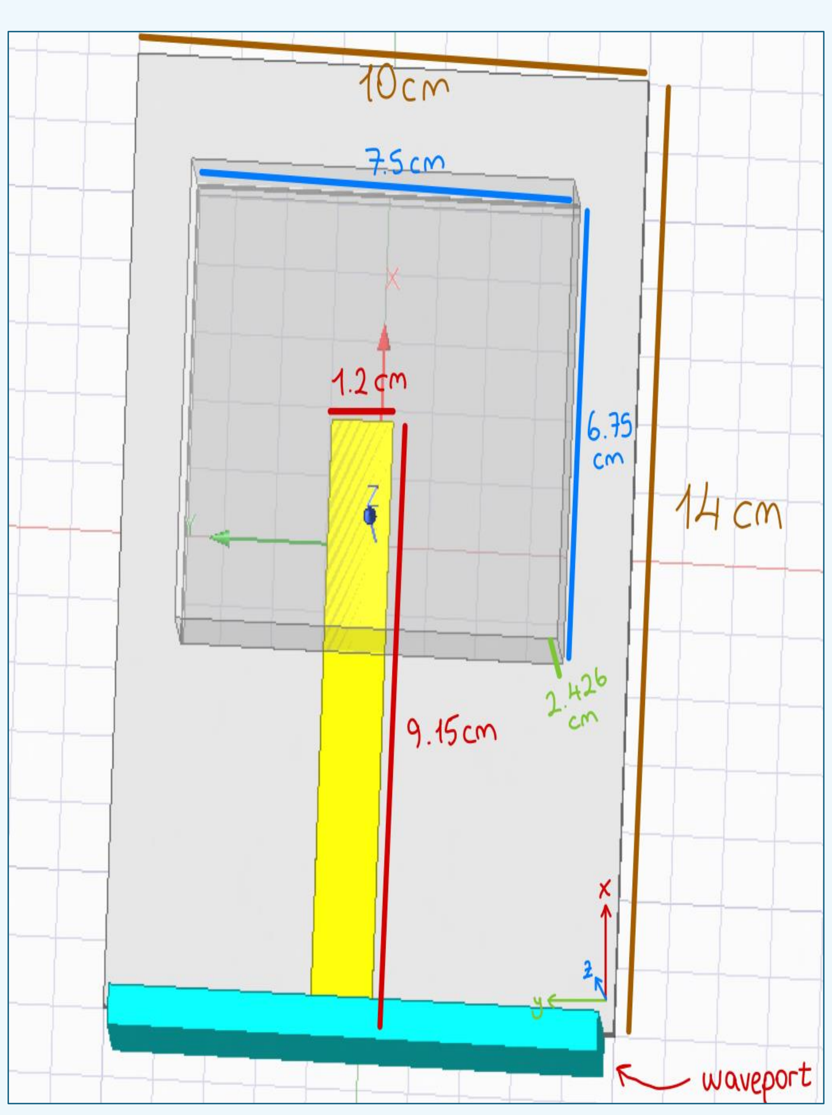
Ground plane: copper

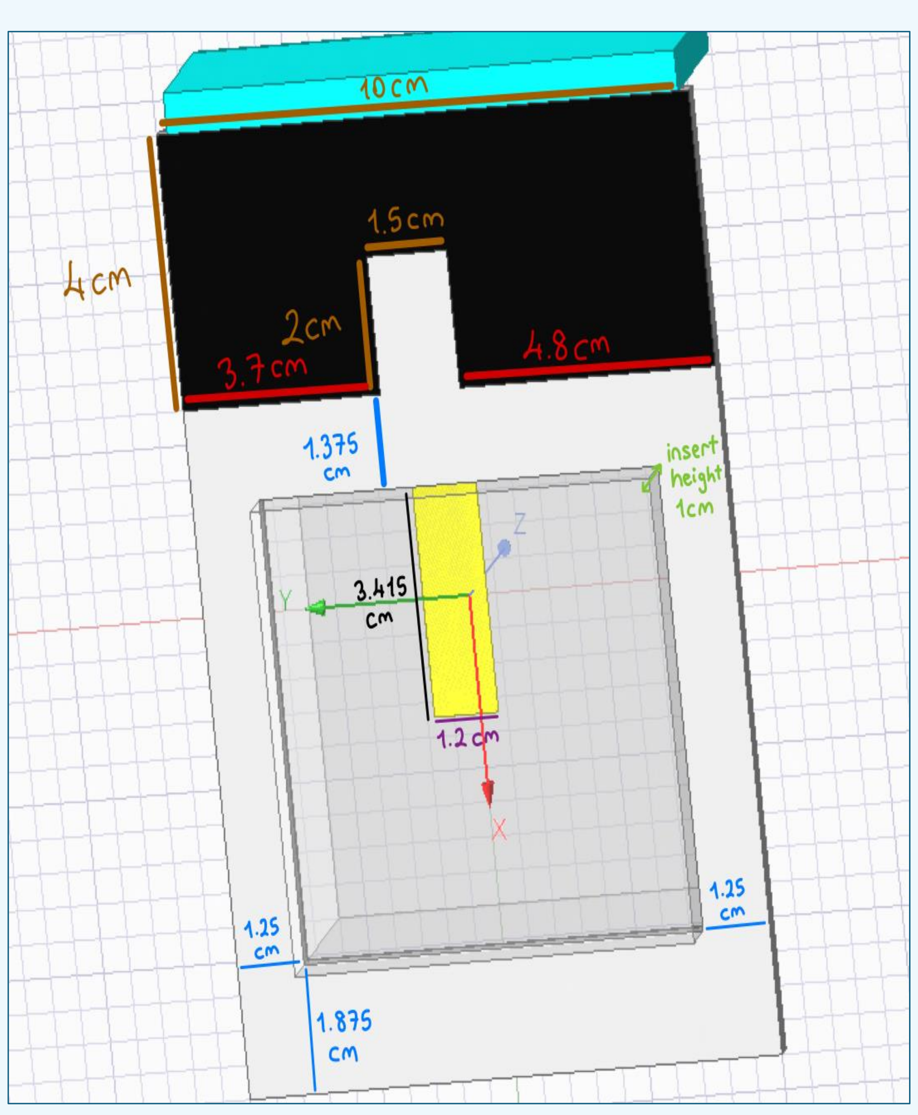
Substrate: PET (Polyethylene) ($\varepsilon_r = 2.25$)

Microstrip transmission line: copper

Dielectric resonators: Silicone Elastomer ($\varepsilon_r = 2.5$)

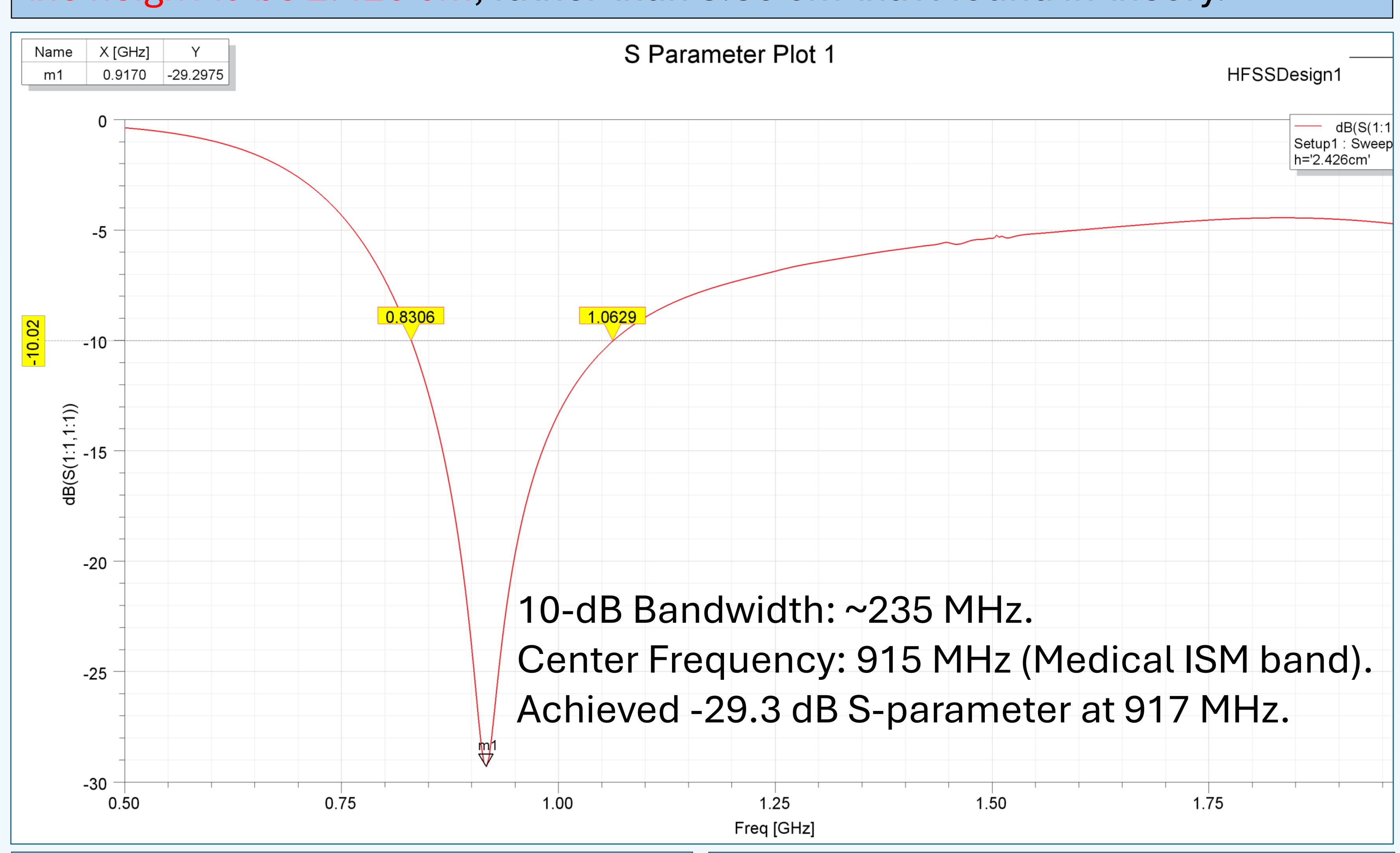


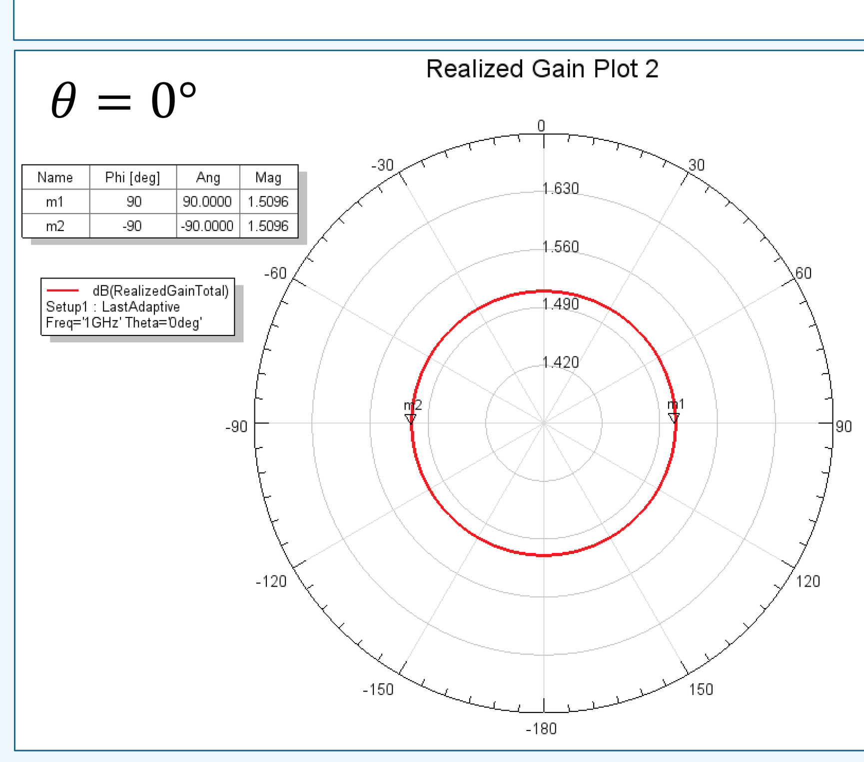


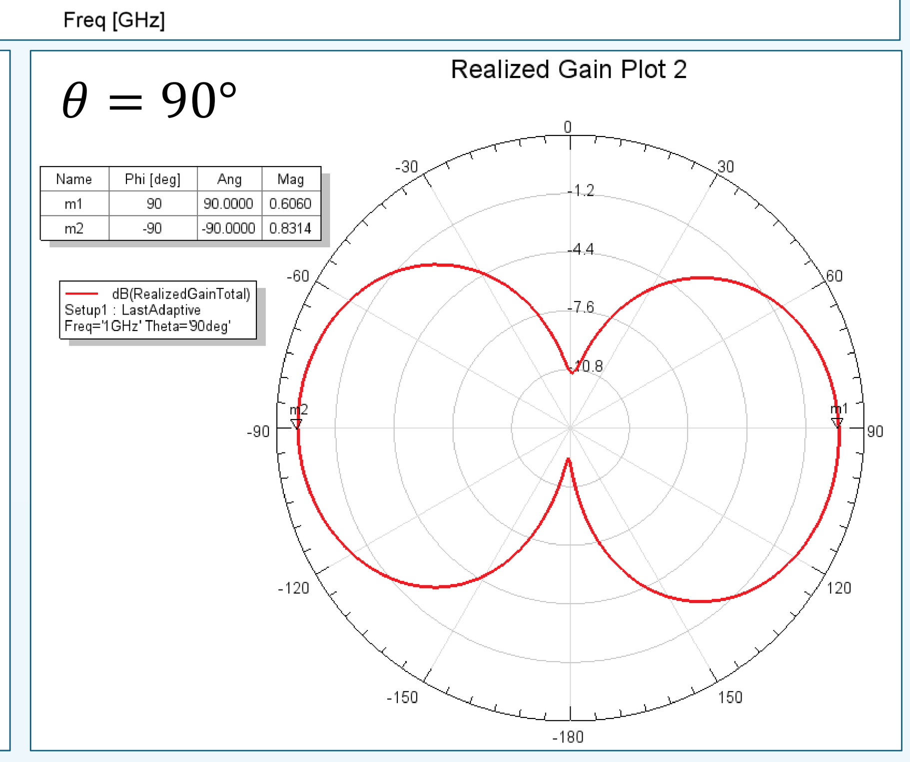


Further Optimizations & Simulation Results

To obtain better BW performance and low-profile design, I have optimized the height to be 2.426 cm, rather than 3.36 cm that I found in theory.







[1] R. D. Richtmyer, "Dielectric Resonators," J. Appl. Phys., Vol. 10, June 1939, pp. 391- 398. **[2]** R. K. Mongia and P. Bhartia, "Dielectric Resonator Antennas—A Review and General Design Relations for Resonant Frequency and Bandwidth," International Journal of Microwave and Millimeter-Wave Computer Aided-Engineering, vol. 4, no. 3, pp. 230- 247, Jan. 1994. **[3]** M. Abedian et al., "Wideband rectangular dielectric resonator antenna for low-profile applications," IET Microwaves, Antennas & Propagation (Print), vol. 12, no. 1, pp. 115–119, Dec. 2017, DOI: https://doi.org/10.1049/iet-map.2017.0593. **[4]** Rajesh. K. Mongia and Apisak Ittipiboon, "Theoretical and experimental investigations on rectangular dielectric resonator antennas," IEEE Transactions on Antennas and Propagation, vol. 45, no. 9, pp. 1348–1356, Sep. 1997, DOI: https://doi.org/10.1109/8.623123. **[5]** S. Keyrouz and D. Caratelli, "Dielectric Resonator Antennas: Basic Concepts, Design Guidelines, and Recent Developments at Millimeter-Wave Frequencies", International Journal of Antennas and Propagation Volume 2016, Article ID 6075680, Sept. 2016, DOI: http://dx.doi.org/10.1155/2016/6075680