Size reduced electric monopole mode DRA

Derek GRAY, Toshiaki WATANABE, and Kunitoshi NISHIKAWA
TOYOTA Central Research & Development Labs., Inc.
Nagakute-cho, Aichi-gun, Aichi, 480-1192, Japan
wnabe@mosk.tytlabs.co.jp

1. Introduction

A toroid DRA produces an electric monopole radiation pattern when operated in the $TM_{01\delta}$ mode. The $TM_{01\delta}$ mode is a higher order mode, and thus requires large DRA dimensions and weight, been disadvantageous compared to electrically equivalent wire and microstrip patch antennas. Placing a grounded pin on the axis of a DRA was shown to cause the appearance of an electric monopole mode at a considerably lower frequency than that at which the $TM_{01\delta}$ mode would usually occur [1]. The effect of the axial pin upon a low profile DRA is discussed.

2. Effect of axial pin

A toroid DRA made of low loss ε_r=21 material (tanδ=8.3x10^{-5}) having a height of 15mm, outer diameter of 47mm, and an inner diameter ξ of 14mm was used to build a pin centred DRA similar to [1] on a 200mm x 200mm square aluminium ground plane, Figure 1(A). This DRA was studied using Ansoft HFSS version 8.5™ along with two identical toroid DRAs having outer and inner circumference feeds for comparison, Figure 1(B) and (B`).

Comparing the return loss of configurations (A) and (B), the 14mm diameter pin eliminated coupling to the $TM_{01\delta}$ mode at 2.2GHz, and caused a new mode to appear at a lower frequency than the fundamental $HE_{11\delta}$ mode, Figure 2. Thus, an electric monopole like mode was produced at 1.28GHz; a 42% reduction in resonant frequency compared to the original $TM_{01\delta}$ mode. The pin had little effect upon the $HE_{x1\delta}$ mode resonant frequencies, Figure 2 and Table 1.

Table 1: Eigenmodes of the toroid DRA.

mode	without axial pin f_r (GHz)	with axial pin f_r (GHz)
$HE_{11\delta}$	1.59	1.56
$HE_{21\delta}$	2.02	2.02
$TE_{011+\delta}$	2.04	2.16
$TM_{01\delta}$	2.20	**not observed**
$HE_{31\delta}$	2.52	2.53
$HE_{41\delta}$	3.04	3.04

The inner circumference feed (B`) coupled most strongly to the $TM_{01\delta}$ mode, while the outer circumference feed (B) coupled best to the $HE_{11\delta}$ and $HE_{31\delta}$ modes, Figure 2. The resonances in either return loss characteristic were in good agreement with the resonant frequencies predicted by the eigenmode solver of HFSS™, Table 1.

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The return loss and input impedance of (A) compared favourably with that predicted by HFSS™, with a small frequency offset, Figure 3.

3. Radiation pattern

The radiation patterns of the configuration (A) DRA were measured in an indoor anechoic chamber. The DRA produced an electric monopole radiation pattern in both the elevation and azimuthal planes at 1.29GHz, Figure 4. Compared to a $\lambda_0/4$ wire monopole on an identical ground plane, the azimuthal radiation pattern of the DRA was skewed about 3dB away from the feed probe, Figure 4b.

4. DRA electric field distributions

The electric field in the vicinity of the DRAs was extracted from the HFSS™ models. The magnitude of $\boldsymbol{E}_z$ from HFSS™ for configuration (B`) closely resembled the theoretical distribution for the $TM_{01\delta}$ mode found using the equation given in Table 1 of [2]. Examination of the magnitude of $\boldsymbol{E}_{total}$ from the configuration (B`) HFSS™ model at 2.2GHz, showed that the field strength was greatest at the centre of the toroid and there were troughs at y=±17mm, z=0mm marking the position of the magnetic field loop, Figure 5(B`). With the pin added, configuration (A), the 1.27GHz electric field distribution was radically different from that of the $TM_{01\delta}$ mode, Figure 5(A). Despite producing an electric monopole radiation pattern, this mode did not have a $TM_{01\delta}$ mode distribution within the DRA, as discussed in [1].

5. Effect of pin diameter

Having confirmed the findings of [1] by numerical modelling and experiment, the effect of pin diameter was investigated using a modified version of the HFSS™ configuration (A) model; only the diameter ξ of the perfect electric conductor filled axial hole was varied. As the pin diameter ξ was increased from 2mm to 18mm, the resonant frequencies of the monopole and $HE_{11\delta}$ modes increased due to the reduced volume of dielectric, Figure 6. Also, with a pin diameter of 2mm, the $TM_{01\delta}$ mode was still present at 2.24GHz. Thus, it is possible to build a DRA having two monopole modes.

6. Conclsuions

Placing a metallic pin on the axis of a low profile DRA was shown to produce a new electric monopole mode at a resonant frequency 42% below that of the $TM_{01\delta}$ mode, confirming the results of prior investigators. This would allow a 42% reduction in all antenna dimensions and weight for a fixed operating frequency. The measured radiation patterns and $\boldsymbol{E}$-field distributions were also in agreement with prior work. The effect of the pin upon other modes was investigated, as was the effect of pin diameter.

7. References

[1] R.K. Mongia, “Small electric monopole mode dielectric resonator antenna,” *Electronics Letters*, 1996, vol. 32, no. 11, pp. 947-949.

[2] R.K. Mongia & P. Bhartia, "Dielectric resonator antennas - A review and general design relations for resonant frequency and bandwidth," *International Journal of Microwave and Millimetre-wave Computer-Aided Engineering*, vol. 4, no. 3, pp. 230-247, 1994.

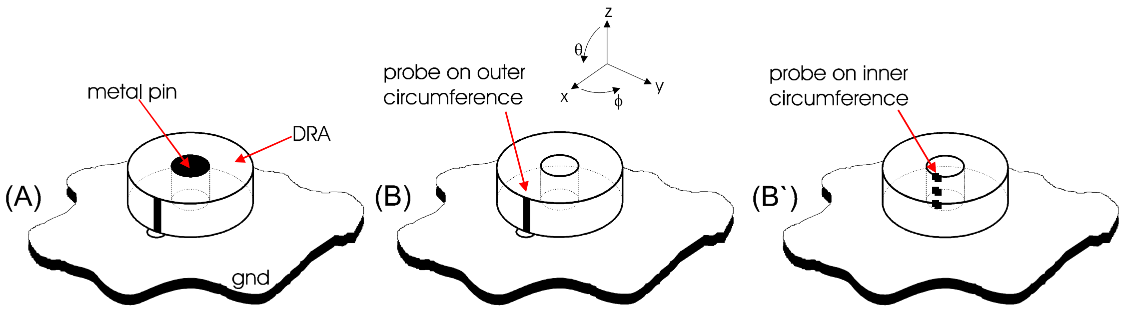

Figure 1: The three electric monopole mode DRA configurations investigated; identical DRAs were used for each configuration.

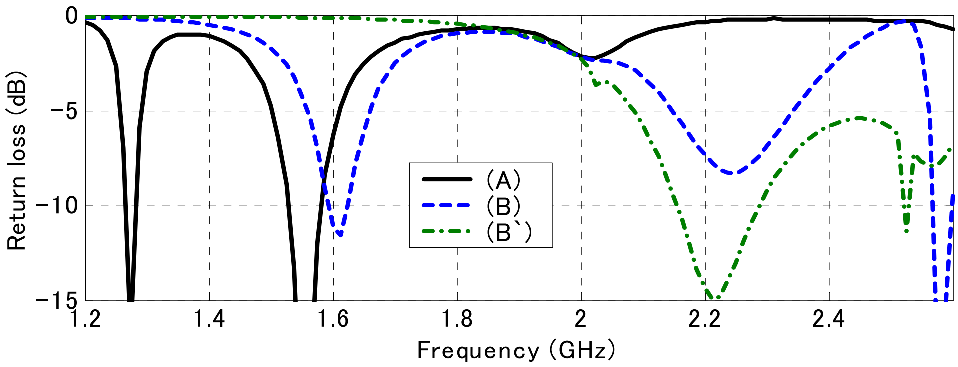

Figure 2: Return loss of the three electric monopole mode DRAs, from HFSS™.

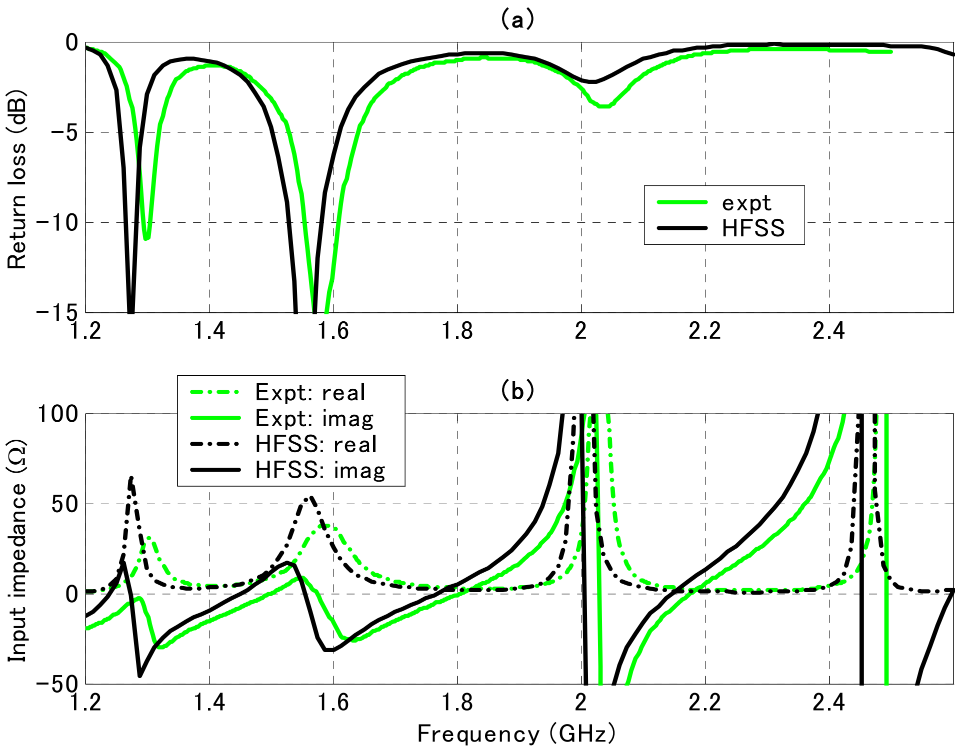

Figure 3: Comparison of measured and HFSS™ input impedance of DRA configuration (A); (a) return loss {HFSS trace same data as (A) of Figure 2}, (b) input impedance.

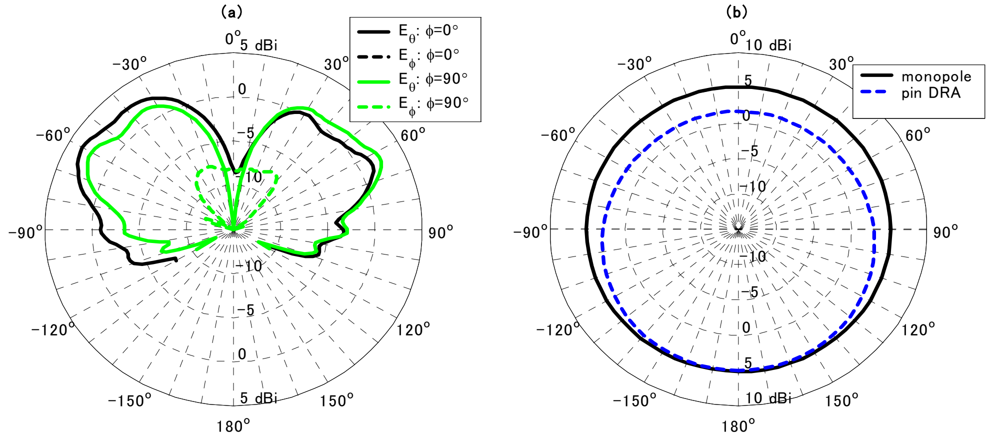

Figure 4: Measured radiation patterns of DRA configuration (A) at 1.29GHz; (a) elevation plane, (b) horizontal plane at θ=65° compared to monopole.

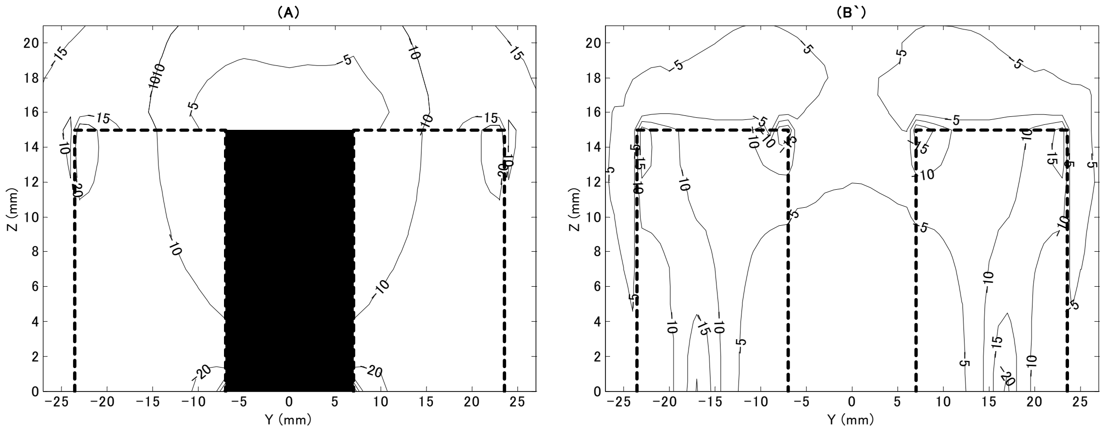

Figure 5: YZ-plane $|\boldsymbol{E}_{total}|$ from configurations (A) and (B`), in dB, from HFSS™; (A) was at 1.27GHz, (B`) was at 2.2GHz.

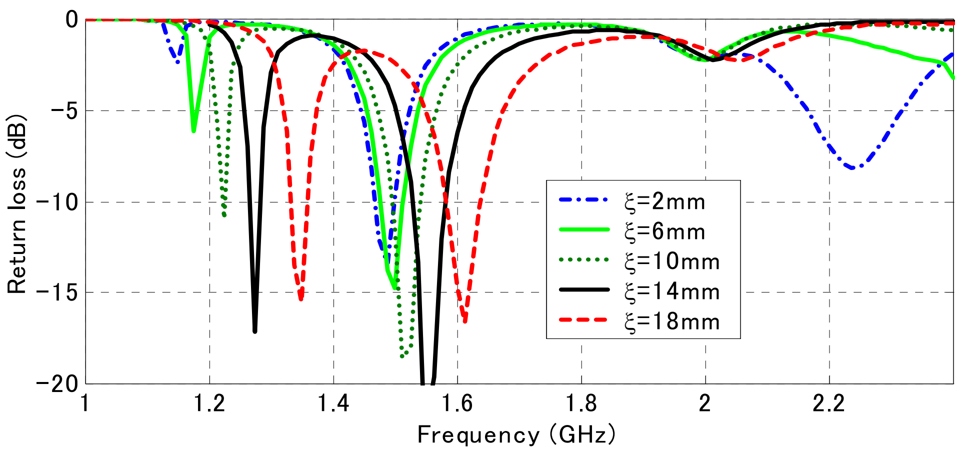

Figure 6: Effect of pin diameter ξ upon return loss of configuration (A), from HFSS™ {ξ=14mm trace same data as trace (A) of Figure 2}.