Proceedings of ISAP 2014, Kaohsiung, Taiwan, Dec. 2-5, 2014

Effect of Aspect Ratio on $TE_{01\delta}$ Mode DRA

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***Abstract* – A lowest order magnetic dipole mode isolated cylindrical DRA was investigated experimentally and using the surface equivalence principal and finite element method solvers in a commercially available software. The height to radius ratio of these DRAs for a fixed resonant frequency was found to vary non-linearly, as predicted by prior theory. An initial 30mm high, 15.4mm radius horizontally polarized DRA was prepared for 2.3GHz band licensed video communications from a small UAV to ground station.**

***Index Terms* — Dielectric resonator antennas, unmanned aerial vehicles.**

I. INTRODUCTION

Remotely supervised or remotely piloted small Unmanned Aerial Vehicles (UAVs) are considered to be applicable to a range of civilian applications such as border policing, power and pipe line monitoring, environmental monitoring and search & rescue [1]. A constant cross section – constant chord swept wing, tailless small UAV was originally developed for tuna spotting from trawlers at sea [2]. With better than 15 hours endurance, it is now used for many of the above mentioned applications. Yaw control is by vertical winglets at the outer end of each wing. As the only vertical structures on the airframe, the winglets additionally serve as housings for command/telemetry antennas [2]. The winglet modem antennas used to date are vertically polarized dipoles. Due to the Transverse Magnetic (TM) polarization relative to the long thin wings, a high level of interaction is expected. Changing to horizontally polarized Transverse Electric (TE) magnetic dipole antennas should decrease airframe interaction and give less nulling.

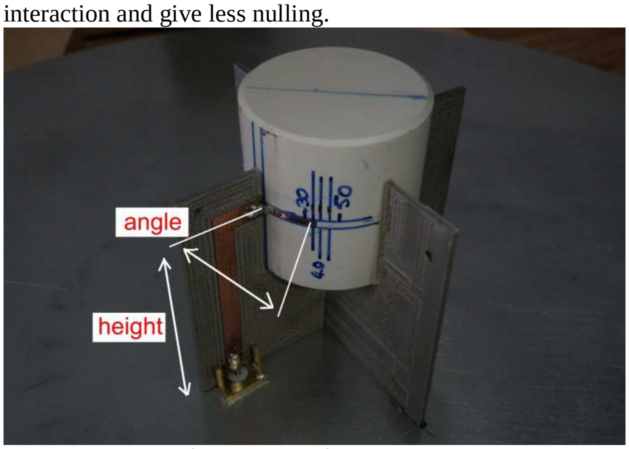

Fig. 1. Photograph of microstrip line fed $TE_{01\delta}$ mode DRA; with printed dipole feed arc angle and DRA height above ground plane marked.

As an alternative to microstrip technology for producing a horizontally polarized TE dipole radiation pattern [3, 4], a $TE_{01\delta}$ magnetic dipole mode DRA was investigated [5, 6]. Here, the printed dipole feed from [6] was used to feed a series of isolated $TE_{01\delta}$ mode DRAs for an aspect ratio study, Fig. 1. The available DRA was then fed by microstrip line over a gain compliance ground plane, in preparation for placement on a mock airframe.

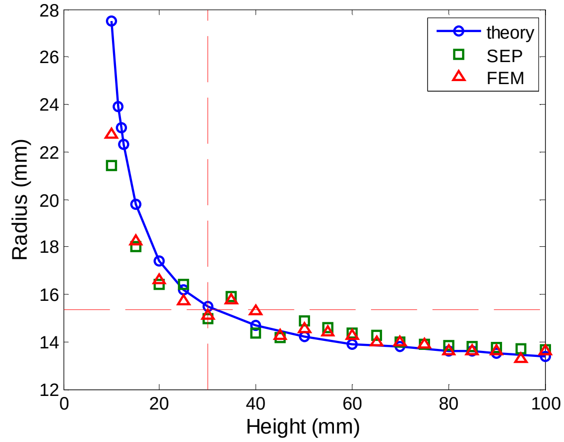

Fig. 2. Radius to height variation of 2.38GHz $TE_{01\delta}$ mode DRA; -- indicates the available DRA, theory from equation (6) of [5].

II. ISOLATED $TE_{01\delta}$ MODE DRA

A 15.4mm radius, 30mm high cylinder of Type A material (ε_r=12.6±0.5) was supplied by NGK Technical Ceramics. In prior work, ε_r of that batch was found to be 12.3 [6]. As in [6], the arc angle of a 1mm wide conductive strip printed dipole feed was varied until a minimal S_{11} was found; half of the printed dipole is visible in Fig. 1. The resonant frequency was found to be 2.38GHz for both the Surface Equivalence Principal (SEP) and Finite Element Method (FEM) models in FEKO™, Fig. 2. A series of optimization simulations were run using both SEP and FEM to find the optimum DRA radius for different DRA heights from 10mm to 100mm, at 2.38GHz; which corresponded to a/H aspect ratios of 5.5 down to 0.3 in [5]. The height to radius relationship was found to be nonlinear, and agreed well with theory from equation (6) of [5]. For DRA heights greater than 60mm, the radii values approached an asymptote of 13.5mm, while the printed dipole angle stabilized at 48°.

The radiation characteristics of the isolated DRAs changed with aspect ratio. As the DRA height was increased from 10mm to 100mm, the peak directivity changed from 2.2dBi to 3.8dBi; these more "pencil like" designs had higher directivity. As equal gain in the horizontal plane is desirable for the envisioned UAV application, the circular asymmetry was noted and had a complex relationship with DRA aspect ratio, Fig. 3. The available 30mm high DRA was found to have relatively low asymmetry.

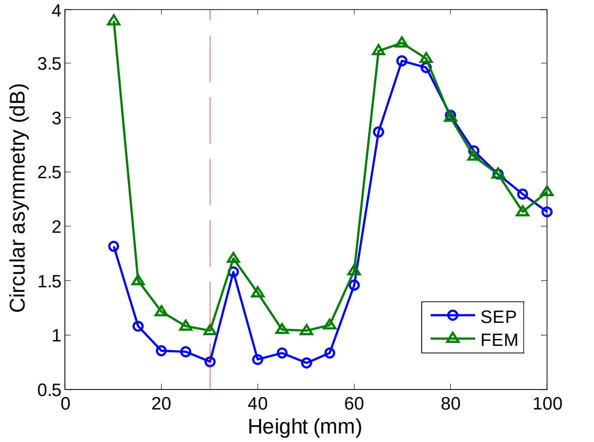

Fig. 3. Horizontal plane radiation pattern asymmetry variation with 2.38GHz $TE_{01\delta}$ mode DRA height, from FEKO™; -- indicates the available DRA.

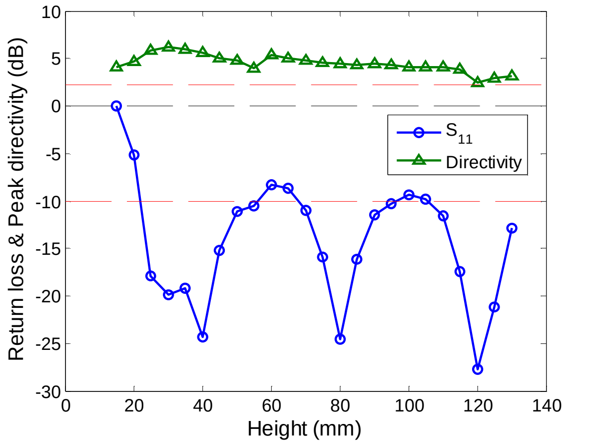

Fig. 4. Variation of 2.3GHz return loss and peak directivity of the microstrip line fed available DRA with height above ground plane, from FEKO™.

III. $TE_{01\delta}$ Mode DRA Above Ground Plane

The available DRA was simulated using the SEP solver over a 130mm radius gain compliance ground plane, while fed by a single 50Ω microstrip line on a support structure made of 1.524mm thickness Arlon MED AD255c (ε_r=2.55), as per Fig. 1. The AD255c support caused the resonant frequency of the $TE_{01\delta}$ mode to decrease to 2.3GHz.

As the DRA height was increased from 16mm to 130mm (one wavelength), the peak directivity decreased and the angle of the peak tended toward 90°, while the return loss went through a series of peaks and troughs, Fig. 4. The return loss minimum DRA height of 40mm was built and tested on a 150mm radius ground plane, Fig. 1. There was reasonable agreement with the FEKO™ simulation, Fig. 5.

IV. Performance on a Small UAV Mock-Up

The DRA was simulated in FEKO™ in the starboard winglet position on a 1.3 meter wingspan mockup of the small UAV. The return loss moved up 50MHz compared to that on the circular ground plane, Fig. 5. The horizontally polarized radiation pattern was satisfactory, other than a sharp null from shadowing by the fuselage, Fig. 6.

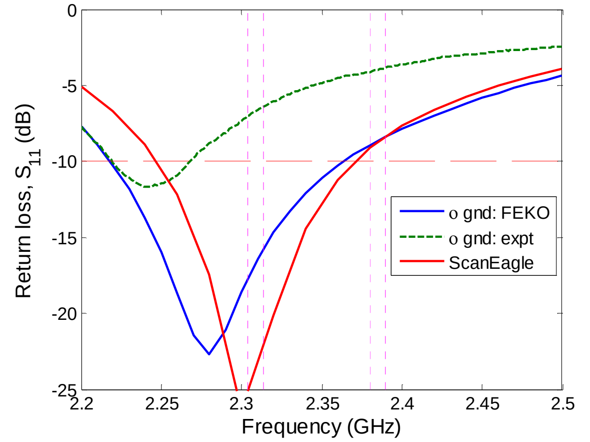

Fig. 5. Return loss of $TE_{01\delta}$ mode DRA on 150mm radius ground plane (as per Fig. 1) and ScanEagle™ mock-up; -- indicates licensed video bands.

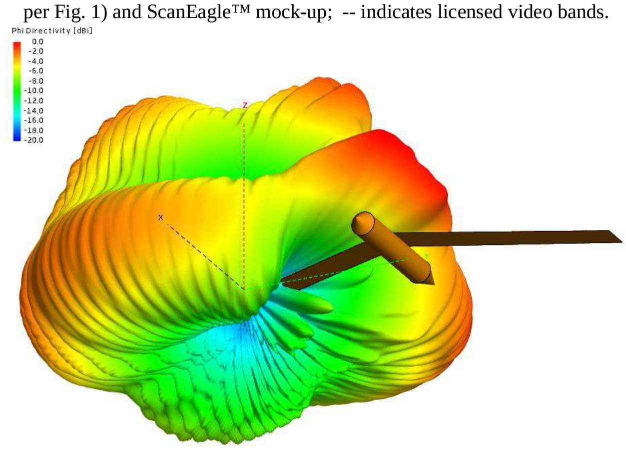

Fig. 6. Normalized 2.3GHz E_φ radiation pattern of $TE_{01\delta}$ mode DRA on ScanEagle™ UAV mock-up, from FEKO™.

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