Defected ground structure to reduce mutual coupling between cylindrical dielectric resonator antennas

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Use of a simple ring-shaped defected ground structure is experimentally demonstrated to suppress considerable mutual coupling between two cylindrical dielectric resonators. About 5 dB suppression has been obtained near the operating frequency around 3.3 GHz. The radiation characteristics with and without defect in the ground plane are also reported.

Introduction: The dielectric resonator antenna (DRA) has been a popular choice for high efficiency systems, particularly at higher frequency bands. Array applications of DRAs have been explored for both circularly and linearly polarised radiations [1–4]. The mutual coupling between adjacent elements occurring in an array environment has been studied in [5–7]. An experimental investigation was reported in [6] showing a quantitative change in S_{12} values between a pair of cylindrical DRAs (CDRAs) with their separation, both in the E- and H-planes. Another thorough investigation [7] provides important aspects causing mutual coupling between the CDRAs, including some important relationships between the mutual coupling and the DRA parameters.

Researchers are seeking techniques to reduce the mutual coupling between DRAs, e.g. [8], where an artificial magnetic conductor ground plane has been theoretically examined to suppress a considerable amount of mutual coupling between the CDRAs. Almost simultaneously, the present authors have introduced a ring-shaped defected ground structure (DGS) indicating possible application in reducing mutual coupling between two microstrip elements [9].

In this Letter, we experimentally demonstrate considerable reduction in mutual coupling between two CDRAs using a simple ring-shaped defect in the ground plane. The effect of the defect on the input impedance and radiation property of a CDRA has also been examined using a set of prototypes.

Structure: A two-element E-plane coupled probe-fed CDRA with a ring-shaped DGS surrounding one of them is shown in Figs. 1 and 2. The material and the dimensions of the CDRA were chosen close to that used in [6] to operate near the mid of S-band but the final design was executed using [10] after the DRAs were fabricated and characterised. A probe having optimised dimensions shows perfectly matched input impedance of a CDRA when located touching its conformal surface. Small pieces of copper tape were used to maintain good contact between the probe and the DRA and thus any unwanted radiation from the probe was avoided. Zinc tungstate ($ZnWO_4$) has been used as the dielectric material ($\varepsilon_r = 14.2$) for our in-house fabrication.

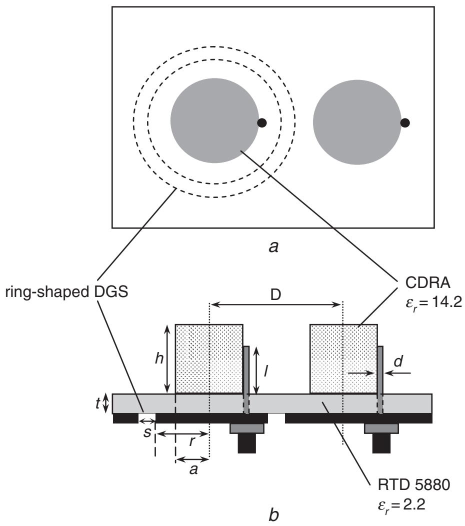

Fig. 1 *Two coax-fed CDRAs mounted on thin RT-duroid substrate with ring-shaped defected ground structure*

a Top view
b Cross-sectional view

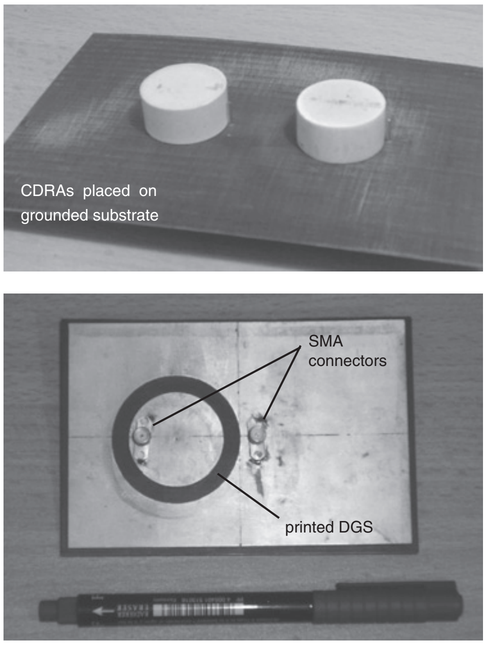

Fig. 2 *Photographs of prototype from top and bottom faces*

To print the defect on a ground plane we had to use a very thin RT-duroid sheet. The upper side of the substrate bears no metal cladding and the CDRAs are directly placed on the substrate, and on the other side, the defect was created by etching out a 6 mm ($\simeq 0.1\lambda_g$) wide circular ring. The ring is strategically located, maintaining equal distance from each DRA, where the CDRAs are separated by about $\lambda/2$ distance. The dimensions of the defect were optimised using simulated data obtained using [10], the resulting parameters are: $a = 10.95$ mm, $h = 10.9$ mm, $l = 8.5$ mm, $d = 1.25$ mm, $t = 0.508$ mm, ε_r(substrate) $= 2.3$, $s = 6$ mm, $r = 18.95$ mm.

Results and discussion: The measured results of the prototype obtained using Agilent's E8363B network analyser and a fully automated anechoic chamber, respectively, are presented. Fig. 3 shows measured S_{21} against frequency around resonance along with the simulated results with and without DGS. The measurement shows about 5 dB reduction in the mutual coupling between two CDRAs in the presence of the DGS and closely agrees the simulated prediction, although the measured S_{21} curve around resonance indicates lower values, in either case compared to the predicted data. Various losses and fabrication irregularities may be attributed to the relative deviation. Though not shown, the reduction of mutual coupling in the H-plane was obtained of the order of 3 dB.

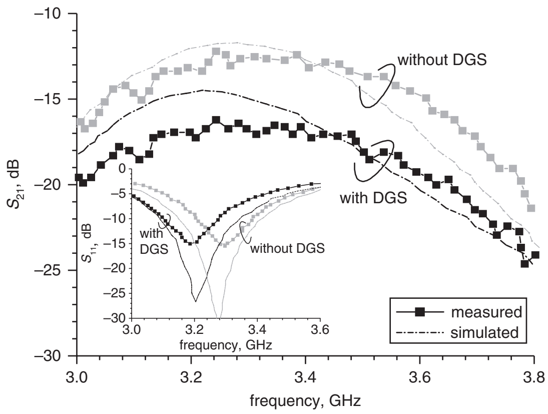

Fig. 3 *Measured and simulated S_{12} against frequency showing E-plane mutual coupling between prototypes*

Inset: Return loss curves of single CDRA with and without DGS
$a = 10.95$ mm, $h = 10.9$ mm, $l = 8.5$ mm, $d = 1.25$ mm, $t = 0.508$ mm, ε_r(substrate) $= 2.3$, $s = 6$ mm, $r = 18.95$ mm

The defect, resulting in 3–5 dB suppression in the S_{21} value, indeed shows a nominal effect on S_{11}, as is examined in the inset of Fig. 3. The operating frequency of a single CDRA with DGS shifts to 3.2 GHz from its value of 3.25 GHz, obtained using a normal ground plane.

The radiation characteristics of an individual CDRA with and without DGS are experimentally examined in Fig. 4. No significant change in peak gain and radiation pattern caused by the presence of the DGS is revealed. Only an increase in sidelobe level (3–5 dB) occurring around $\pm 120^\circ$ is apparent. No backward radiation is found. Similarly, no change in the cross-polarised level is observed. It is found to be about 15–20 dB below the peak value.

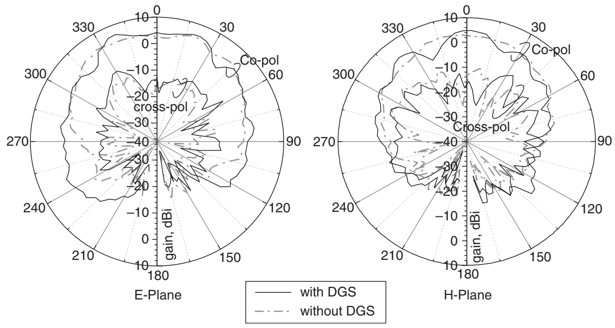

Fig. 4 *Measured E- and H-plane radiation patterns of two E-plane coupled coax-fed CDRAs mounted on 31 mil RT-duroid substrate with and without DGS*

$a = 10.95$ mm, $h = 10.9$ mm, $l = 8.5$ mm, $d = 1.25$ mm, $t = 0.508$ mm, ε_r(substrate) $= 2.3$, $s = 6$ mm, $r = 18.95$ mm

Conclusion: Noticeable reduction in mutual coupling among CDRA array elements can be efficiently used using a simple ring-shaped DGS. No backward radiation is observed, except for a 3–5 dB increase in sidelobe occurring near 120°.

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