Substrate Integrated Dielectric Resonator Antennas in *Ka* Band

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***Abstract*- A kind of low-profile substrate integrated dielectric resonator antenna (SIDRA) is presented in this paper. The SIDRAs can be implemented with a two-layer printed circuit board (PCB) process conveniently, in which the integrated dielectric resonators are fabricated in the top layer and fed by the compact substrate integrated waveguide (SIW) through the transverse coupling slots within the bottom layer. The prototypes exhibit good radiation performances in *Ka* band, and the 10-dB bandwidth can be easily extended from around 12% to 25% with stable broadside radiation patterns. These antennas show the advantages of low profile, high radiation efficiency, easy manufacture, etc.**

***Keywords*- Dielectric resonator antenna (DRA), millimeter wave antenna, printed circuit board (PCB), substrate integrated waveguide (SIW).**

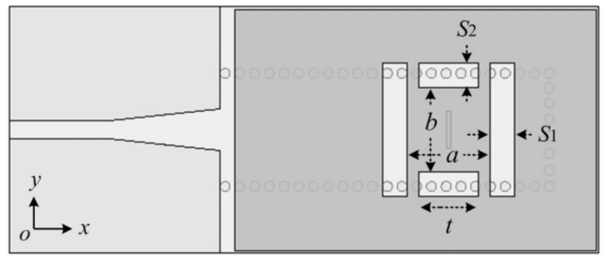
I. INTRODUCTION

The recent years have witnessed a significant focus and interest paid towards the development of dielectric resonator antennas (DRAs). They have been widely investigated for their small size, high radiation efficiency, and flexible excitation scheme. Most important of all, the DRA is free from metallic loss and surface wave loss. These favorable characteristics make them attractive for a wide variety of wireless applications from microwave frequency to millimeter wave bands [1]-[5]. However, the discrete elements of the DRAs are usually with a length-to-height (diameter-to-height) ratio of about two or less, and not suitable for many low-profile integration applications.

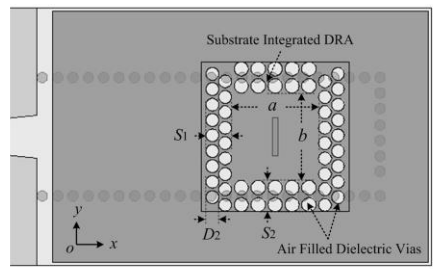
Nowadays, it is a trend to realize the integrated and multifunctional designs for DRA [6]-[9], in which the integrated DR will be used to replace the discrete one. Differently from the method employed in [8] and [9], the presented SIDRAs in our design can be totally accomplished with PCB or low-temperature co-fired ceramic (LTCC) process conveniently [10]-[12].

II. SUBSTRATE INTEGRATED DIELECTRIC RESONATOR ANTENNAS (SIDRAs)

In the following SIDRAs, the *Rogers RT6010* (ε_r = 10.2, $tan\delta$ = 0.0031 at 10 GHz) with a thickness of 0.635 mm is utilized to realize the low-profile SIDRs, and the *Rogers RT5880* (ε_r = 2.2, $tan\delta$ = 0.0013 at 10 GHz) with a thickness of 0.254 mm is employed to create the compact feeding SIW. The SIDRAs resonate at the TE_{11} mode for linear polarization, and the feeding SIW operates at the dominant mode of TE_{10}.



(a)



(b)

Fig. 1. Structure of the proposed antennas. (a) modified SIDRA, and (b) SIDRA.

The antennas are simulated and optimized by using Ansoft High Frequency Structure Simulator (HFSS).

A. Modified SIDRA

Fig. 1(a) shows the structure and parameters of the modified SIDRA. The SIDR is integrated on the top substrate with $S_1 \geqslant \lambda_0/10$ and $S_2 \geqslant \lambda_0/10$ (λ_0 is the wavelength at center frequency in free space). A narrow slot with length of L_s and width of W_s is etched on the broad wall of the feeding SIW to couple the energy to the SIDR, and the width of the slot is kept small relative to the wavelength of operation. For the SIDRA with $t/a \geq 0.7$, as shown in Fig. 1, the attached dielectric material areas along *x*-axis correspond to the minimum *H*-field intensity for the TE^y_{111} operating mode, and have almost no effect on SIDRA's field distributions and radiation performances, then the dimensions *a* and *b* of the SIDRA can be determined for a desired operation frequency.

B. SIDRA

Fig. 1(b) illustrates the configuration and parameters of the SIDRA, in which the perforated air-wall is used as the boundary of the SIDR. The perforated air-wall presents a similar electromagnetic characteristic as that of the vacuum

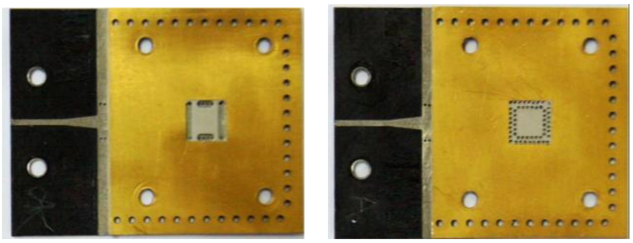

(a) (b)

Fig. 2. Photograph of fabricated antennas. (a) modified SIDRA, and (b) SIDRA.

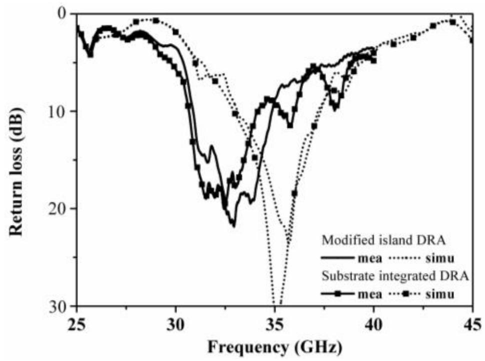
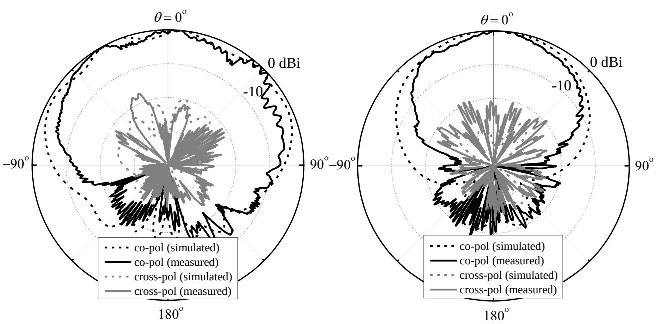


Fig. 3. Simulated and measured return losses of the modified SIDRA and the SIDRA.



(a) (b)

Fig. 4. Simulated and measured normalized radiation patterns of the SIDRA at 33.5 GHz. (a) E(x-z)-plane and (b) H(y-z)-plane.

under proper design, and the SIDRA exhibits similar performances as the modified one.

Two prototype antennas were designed and fabricated using PCB process in 35 GHz band. Fig. 2 shows the photograph of the assembled antennas, in which the size a = b = 3.4 mm. The return losses of the two antennas were measured with the Agilent E8363B vector network analyzer, and Fig. 3 describes their measured results together with the simulated ones. The measured return losses follow the trend of the simulated ones well with a slight frequency shifting of about 7% which may be caused by the assembly error and fabrication tolerance. Two SIDRAs show the measured 10-dB bandwidth of about 11%, which agrees well with the simulated result. Moreover, a good consistency of the measured results is observed in Fig. 3 between the SIDRA and the modified SIDRA. Fig. 4 presents the measured normalized radiation patterns of the SIDRA at 33.5 GHz, and the modified one shows similar radiation patterns with an average gain of 5 dBi over the band.

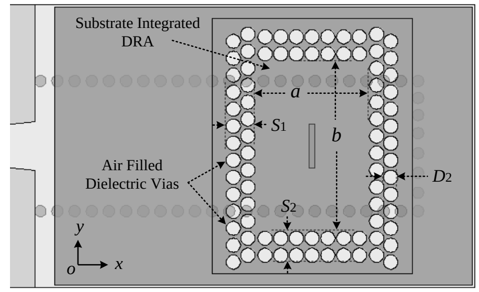


Fig. 5. Structure of the broadband SIDRA.

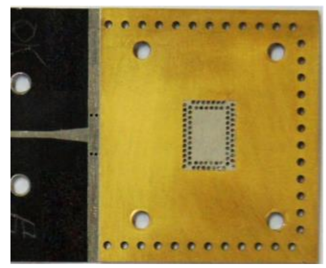


Fig. 6. Photograph of fabricated broadband SIDRA.

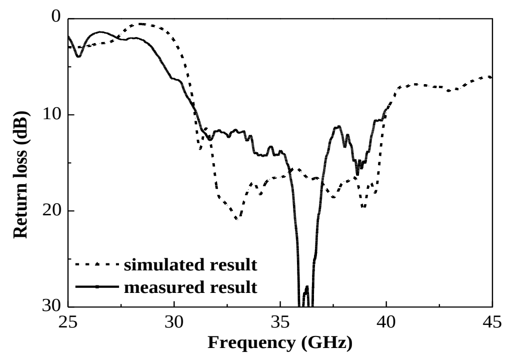


Fig. 7. Simulated and measured return losses of the broadband SIDRA.

C. Broadband SIDRA

Fig. 5 shows the configuration and parameters of the broadband SIDRA, in which the coupling slot etched on the feeding SIW is utilized as the SIDR exciting structure and simultaneously acts as an effective resonant radiator. The coupling slot can be modeled by a magnetic current source along y-axis, and it resonates at the first mode with the overall length of approximate a half wavelength inside the dielectric material. Under this condition, the coupling slot radiates like a magnetic dipole along y-axis with broadside radiation patterns. By combining the resonance of the exciting slot with that of the SIDR, a compact broad SIDRA can be achieved, and a consistent radiation performance will be obtained over the enhanced bandwidth. An antenna example is designed and fabricated in *Ka* band using the standard PCB process, and its photograph is presented in Fig. 6 with the optimal geometric parameters a = 4 mm, b = 6 mm. Fig. 7 depicts the measured and simulated its return losses, and good agreement between them has been observed. The fabricated broadband SIDRA offers an enhanced bandwidth of about 25% (from 31 to 40 GHz) for 10 dB return loss, which is two times higher than that of the previous SIDRA. The prototype was also measured in a far-field anechoic chamber, and its radiation patterns are similar with the ones of the previous SIDRA and stable and not shown for brevity. The measured gain ranges from 4.1 to 5.4 dBi over the passband

III. CONCLUSION

A kind of SIDRA has been presented including the design schemes, procedures, and the simulation models. The antennas can be totally implemented with PCB process conveniently, and feature the advantages of low profile, compact size, easy manufacture, high radiation efficiency, and convenient integration with other planar circuits.

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