Circularly Polarized Substrate Integrated Dielectric Resonator Antenna

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***Abstract*—This paper proposes a novel circularly polarized (CP) substrate integrated dielectric resonator antenna (SIDRA). It is fed by a half-mode substrate integrated waveguide (HMSIW) through a pair of cross-slots. The feeding HMSIW and radiator of the proposed SIDRA can be fully integrated together based on the simple printed circuit board (PCB) technology. The proposed antenna has the merits of low profile, low cost, high efficiency, and easy integration.**

Index Terms*—*Substrate integrated dielectric resonator antenna (SIDRA), half-mode substrate integrated waveguide (HMSIW), circularly polarized (CP), cross-slot.

I. INTRODUCTION

In recent years, amounts of studies have focused attention on the dielectric resonator antennas (DRAs) for their good radiation performance, such as wide bandwidth, light weight, and high radiation efficiency [1]-[3]. Circularly polarized (CP) antennas have more and more wide spread application in wireless and satellite communication systems as less influences caused by polarization mismatching [2].

Half-mode substrate integrated waveguide (HMSIW), with the advantages of low profile, low cost, and easy integration, is used to feed DRAs for obtaining CP radiation [4]-[5], but the DRA cannot be easily integrated with its feeding network because of their less length-height ratio. Therefore, it is necessary to design two-dimensional substrate integrated DRA to be incorporated with the feeding structure, which will be easily achieved based on the PCB, low-temperature co-fired ceramic (LTCC), and Micro-electromechanical Systems (MEMS) technologies.

In this paper, a V-band substrate integrated DRA (SIDRA) with the length-height radio of about fifteen is proposed. The SIDRA is fed by HMSIW through a cross-slot to obtain CP radiation. The proposed SIDRA takes the advantages of low profile, easy integration with the planar circuits.

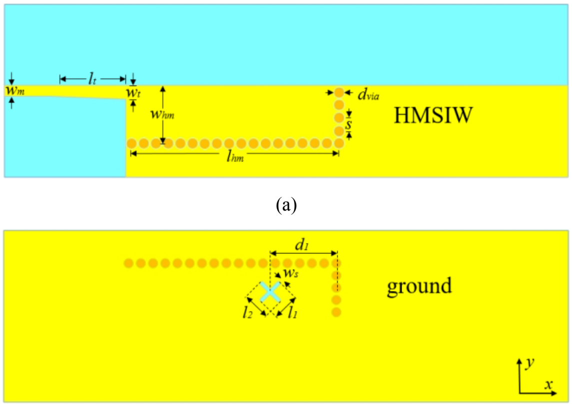
II. ANTENNA CONFIGURATION

A. Feeding HMSIW Configuration

The structure of the feeding HMSIW which operates at the fundamental mode of $TE_{0.5,0}$ is depicted in Fig. 1. It is structured with a row of metallic via-holes on a low-loss substrate printed with two metallic patches on both sides. In order to feed the DRA, a pair of cross-slots is etched on the top side of HMSIW, and another row of metallic vias are distributed to form a quarter-wavelength shorting wall.

To design the SIDRA, the first step is to select the HMSIW cutoff frequency f_c appropriately [4]. The parameters of w_{hm}, d_{via} and s donate the width of the HMSIW, via diameter and the spacing between adjacent vias, respectively. They can be calculated according to [5]. As shown in Fig. 1(b), a pair of cross-slots with unequal length is etched on the ground. The energy is coupled from the feeding HMSIW to DRA through the slots, and then two orthogonal resonant modes with roughly equal amplitudes and 90° phase differences are excited. Thus, a circularly polarized radiation can be obtained [6].

The dimensions of the slots can be calculated by the following steps [6]: First, the two slots are assigned to be resonant at two different frequencies: $f_1 = f_{ct} - f$, $f_2 = f_{ct} + f$, where f_{ct} is the center frequency of the antenna and $f << f_{ct}$; Second, l_1, l_2 and d_1 can be initially chosen to be $\lambda_{g1}/2$, $\lambda_{g2}/2$ and $3\lambda_{gct}/4$ (λ_g is the guided wavelength), respectively; Third, the two slots form ±45° with respect to the x-axis; Finally, the parameters of l_1, l_2 and d_1 are optimized to obtain optimum radiation performance using EM software HFSS. Furthermore, a taper transition is designed to realize the impendence matching from microstrip line to the HMSIW [3]-[4].



(a)

(b)

Fig. 1. HMSIW feeding structure (a) bottom-view, (b) top-view

B. SIDRA Antenna

Evolved from a cylindrical isolated DRA, the structure of the SIDRA antenna is illustrated in Figs. 2 and 3. A piece of substrate is printed above the feeding HMSIW, and several air-holes are perforated into the substrate. The air-holes are circularly distributed above the cross-slots. Therefore, the central encircled substrate is isolated with the outer substrate and forms the DRA structure.

The DRA operates at the $TE_{11\delta}$ mode with the resonant frequency of f_{ct}. The dimensions of the isolated DRA, d and h, can be estimated according to [4]. As shown in Figs. 2 and 3, the air via-holes are perforated on the upper substrate (Rogers RT6010) as the SIDRA. Optimizing the diameter of the air-holes d_1 and the angle between the two adjacent air-holes θ, the SIDRA can present the similar field distributions with the isolated DRA structure. The design parameters of the proposed antenna are listed in Table I.

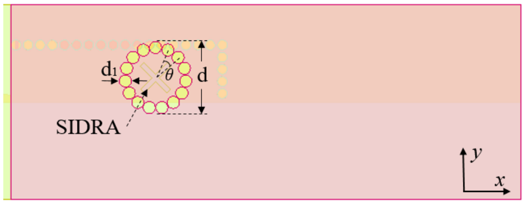


Fig. 2. SIDRA structure

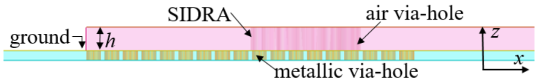


Fig.3. Side view of the antenna

TABLE I. PHYSICAL PARAMETERS OF THE ANTENNA

param.	value	param.	value	param.	value
l_{hm}	8.5mm	l_t	2.3 mm	d_{via}	0.4 mm
w_{hm}	2.4 mm	w_t	0.3 mm	s	0.5 mm
l_1	1.55 mm	d_2	0.5 mm	t	0.254 mm
l_2	1.6 mm	θ	24°	h	0.635 mm

The proposed DRA configuration has a high length-to-height radio, thus it can achieve the simple integration with feeding HMSIW and wide application in planar circuit.

III. RESULTS AND DISCUSSION

The proposed antenna is analyzed and optimized by High Frequency Structure Simulator (HFSS). As shown in Fig. 4, the simulated impedance bandwidth (for $S_{11} \leq -10$ dB) is 4.1% (from 56.4 GHz to 59.8 GHz). Fig. 5 depicts the simulated axial ratio (AR) result, demonstrating a 3-dB AR bandwidth of 3.8% (from 56.8 GHz to 59.0 GHz). By comparing the frequency responses of Fig. 4 and Fig. 5, a conclusion can be drawn that the antenna operation band for AR < 3 dB mostly overlaps the operation band for $S_{11} < -10$ dB. The radiation patterns of the antenna at 58.5 GHz are presented in Fig. 6. It can be seen that a good left-hand CP radiation is obtained. The 3-dB beamwidth in the yz-plane is about 78° and the peak gain of the antenna is about 8.0 dB at 58.5 GHz. As shown in Fig.4, the simulated radiation efficiency is above 80% over the whole operation band and has a maximum of 92% around 56 GHz, indicating that the HMSIW can efficiently feed the SIDRA at V-band.

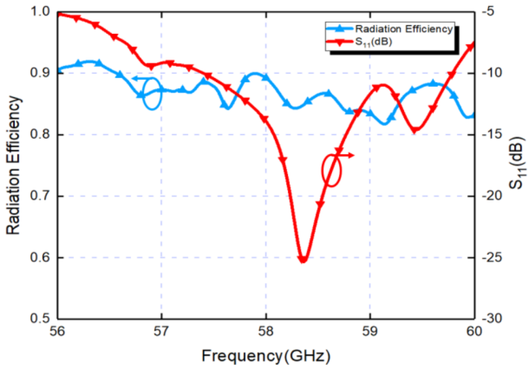


Fig. 4. Simulated return loss and radiation efficiency

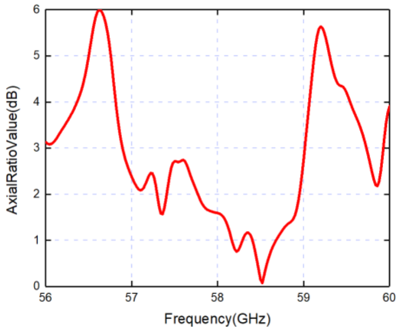
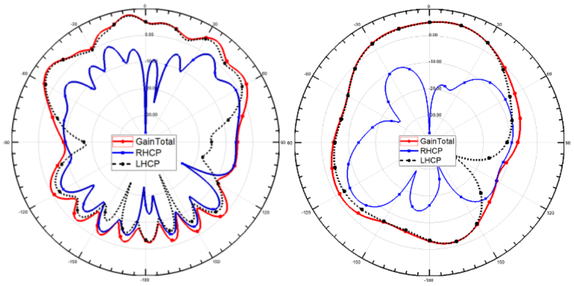


Fig. 5. Simulated Axial Ratio Value



(a) (b)

Fig. 6. Simulated radiation pattern on (a) yz-plane, (b) xz-plane

IV. CONCLUSION

This paper has proposed a novel SIDRA CP antenna based on the PCB technology. The DRA can be designed with incorporation with the feeding HMSIW. The 3-dB AR bandwidth of the SIDRA antenna is 3.8%, and the antenna gain is 8.0 dB at 58.5 GHz. In addition, the antenna achieves a high radiation efficiency of 80% over the whole operation band. The proposed CP SIDRA antenna shows a good radiation performance featuring low profile, high gain, high radiation efficiency, and easy integration with planar circuits.

ACKNOWLEDGEMENT

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