Aperture-coupled Differentially-fed Dielectric Resonator Antenna With/Without Parasitic Patches

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1. Introduction

In recent years, the microwave differential circuit has received increasing attention for its good performance such as the improved noise immunity, lower cost, smaller size, and harmonic rejection [1]. Traditionally, a balun is often used as a transition between the differential circuit and single-ended antenna. However, it inevitably increases the system loss and size. To avoid this problem, some differentially fed antennas have been proposed [2]-[7], i.e., Petosa [2] and Xue [3] et al. proposed the probe-fed wideband differential microstrip antennas for applications that require a low cross-polarization level. It was found that the differentially fed antenna can be characterized using the odd-mode reflection coefficient Γ_{odd} [4], the differential impedance Z_d [5], and the mixed-mode S parameter S_{dd11} [6]. A detailed discussion on these parameters has also been given in [6].

Because of the inherent advantages of its small size, low loss, light weight, the dielectric resonator antenna (DRA) has been studied extensively [7] in the last two decades. Recently, the authors studied strip-coupled differentially fed rectangular DRAs [6], where only the linearly-polarized (LP) DRA was considered. In this paper, the aperture-coupled differentially fed rectangular DRA is investigated. Both linearly- and circularly-polarized (CP) DRAs are studied. A rectangular DRA excited in its fundamental broadside $\mathbf{TE}^y_{111}$ mode at 2.4GHz is used for demonstration. To excite the CP wave, two parasitic patches are attached on the side walls of the DRA [9]. The commercial software Ansoft HFSS was used to simulate the DRA. Measurements were carried out to verify the simulations and reasonable agreement between them was obtained.

2. Linearly-Polarized Differentially fed DRA

Figure 1(a) shows the configuration of the aperture-coupled differentially fed rectangular DRA. By using the dielectric waveguide model (DWM) [10], the DRA is designed to cover the 2.4GHz ISM band (2.4-2.484GHz). The dimensions of the DRA are given by a=31.8mm, b=24.2mm, and d=15.9mm. Its dielectric constant is given by ε_r=10. With reference to the figure, the DRA is excited by two parallel apertures of L_1= L_2=22mm and W_1=W_2=1mm, which are etched on the ground with a size of 100×100mm^2. The distance between the two apertures is 22mm. Two identical 50Ω microstrip transmission feedlines of W_f= 0.56 mm and L_{s1}= L_{s2}=9.5 mm are printed on a dielectric substrate having a dielectric constant of ε_{rs}=2.33 and a thickness of h=1.57mm. The previous commercial broadband (1-18GHz) 3-dB 180^o hybrid coupler [6] was used again to provide the differential signals.

To validate the simulation, an experiment was carried out using a 4-port Agilent N5230A PNA-L series network analyzer. Figure 1(b) shows the measured and simulated mixed-mode S-parameter (|S_{dd11}|) results. Reasonable agreement between the measured and simulated results is observed. The measured and simulated resonated frequency is 2.41GHz and 2.53GHz. The measured and simulated 10-dB differential impedance bandwidth (|S_{dd11}|<-10dB) are 10.79% (2.28GHz~2.54GHz) and 12.52% (2.32GHz~2.63GHz), respectively. The error is mainly due to the imperfect symmetrical of the whole structure.

The far fields of the DRA were measured using a SATIMO Starlab system. The measured and simulated x-z and y-z plane radiation patterns at the resonated frequency are plotted in Figure 2, where a broadside radiation mode is observed. For each radiation plane, the co-polarized field is stronger than cross-polarized field by more than 20dB.

3. Circularly-Polarized Differentially fed DRA

To excite the CP wave, two identical parasitic patches of length $L_{p1}= L_{p2}$=8.2mm and width $W_{p1}= W_{p2}$=2mm are placed on the side walls of DRA used in the previous section. The distances between the edge of DRA and patches is $L_{g1}= L_{g2}$=3.7mm. Other parameters are the same as in previous section. The configuration is shown in Figure 3(a). In the experiment, the two feeding strips were cut from an adhesive conducting tape.

Figure 3(b) shows the measured and simulated mixed-mode S parameter ($|S_{dd11}|$) results. The measured and simulated 10-dB differential impedance bandwidth ($|S_{dd11}|$<-10dB) are 19.87% (2.13GHz~2.6GHz) and 19.25% (2.16GHz~2.62GHz), respectively.

Figure 4(a) shows the measured and simulated ARs in the boresight direction (θ=0º), with good agreement between them is obtained. Both of the measured and simulated ARs are optimum at ~2.45 GHz. From the figure, the measured 3-dB AR bandwidth is 3.06% (2.41GHz~ 2.485GHz), which is basically the same as for a singly fed CP DRA. The measured antenna gain is shown in Figure 4(b), where the gain is about 4.2dBi around the resonance of the DRA. The measured and simulated x-z and y-z plane radiation patterns at f=2.45GHz are plotted in Figure 5, where a broadside radiation mode is observed. For each radiation plane, the right-hand CP (RHCP) field is stronger than the left-hand CP (LHCP) field by more than 30dB in the boresight direction.

4. Conclusion

The aperture-coupled differentially-fed rectangular DRAs have been studied. Both the LP and CP DRAs are studied. For the LP DRA, the fundamental broadside $\mathbf{TE}^{y}_{111}$ mode at 2.4GHz is excited. The measured 10-dB differential impedance bandwidth ($|S_{dd11}|$<-10dB) are ~10.8%. For the CP DRA, the 10-dB differential impedance and 3-dB AR bandwidth of ~19.9 and 3.1% have been found.

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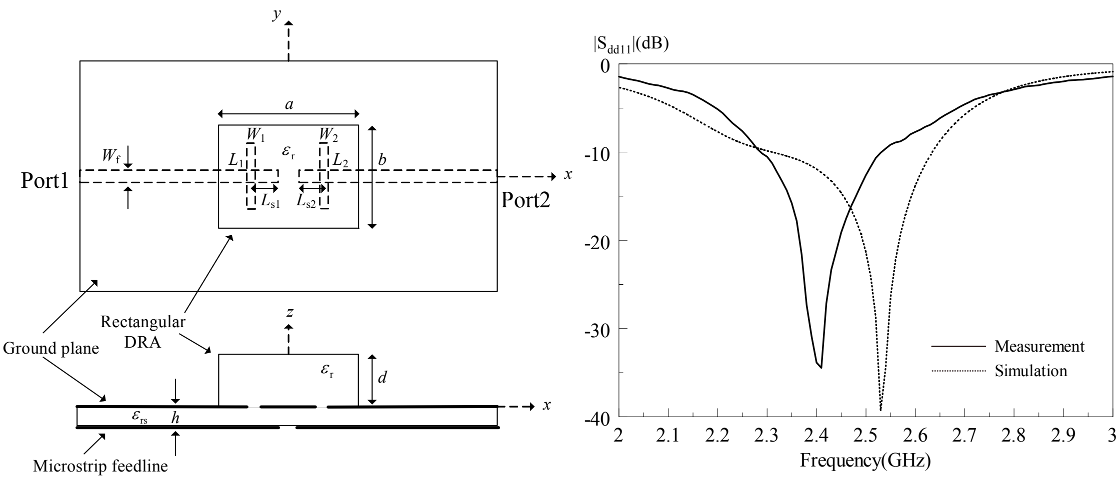

(a) (b)

Figure 1: (a) Configuration and (b) measured and simulated result of mixed-mode S parameter ($|S_{dd11}|$) of the aperture-coupled differentially fed rectangular DRA

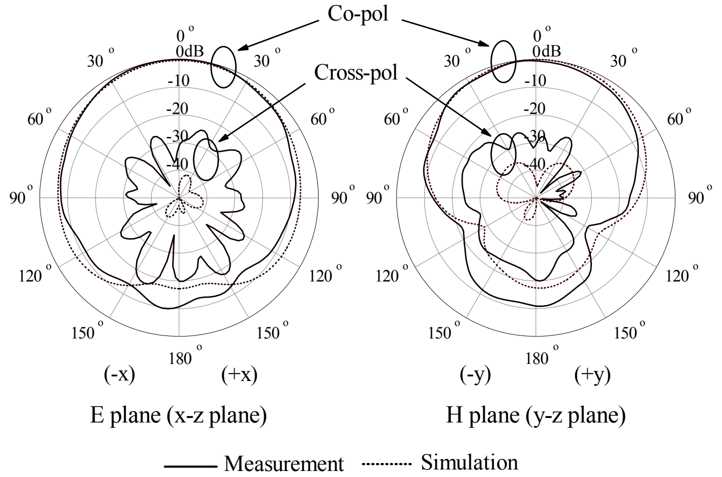

Figure 2: Measured and simulated radiation patterns at the resonated frequency

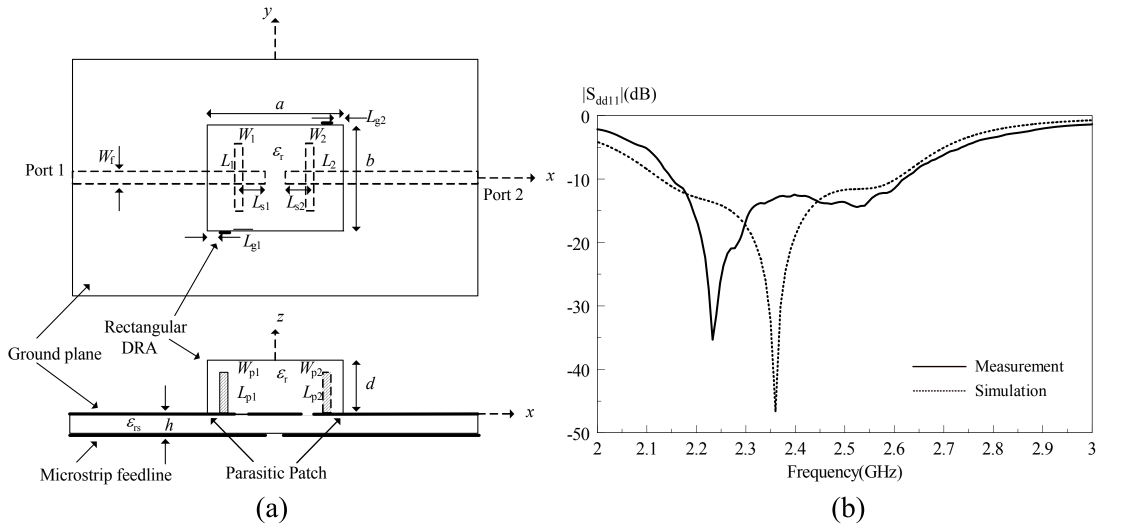

Figure 3: (a) Configuration and (b) measured and simulated mixed-mode S parameter ($|S_{dd11}|$) of the differentially fed rectangular DRA with two parasitic patches.

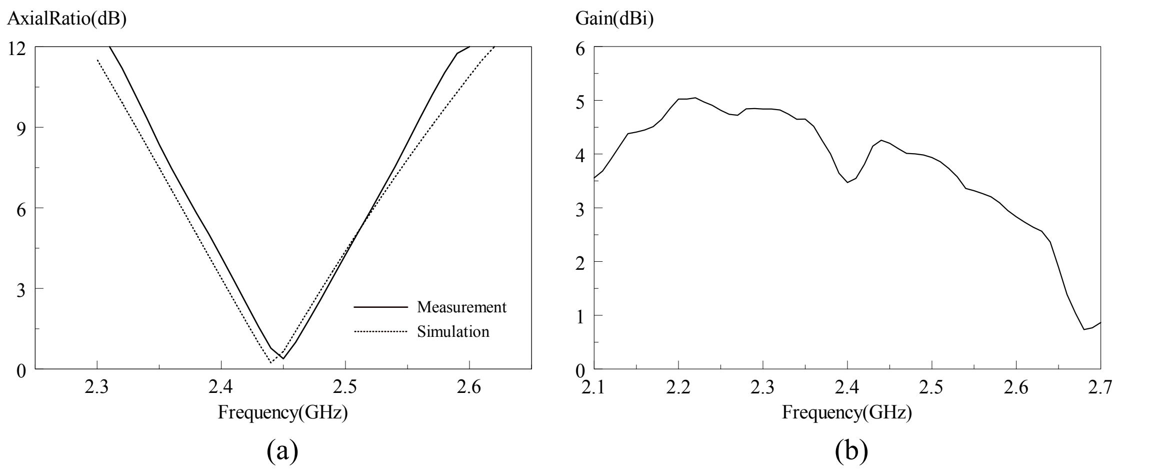

Figure 4: (a) Measured and simulated axial ratios and (b) measured gain of the differentially fed rectangular CP DRA as a function of frequency.

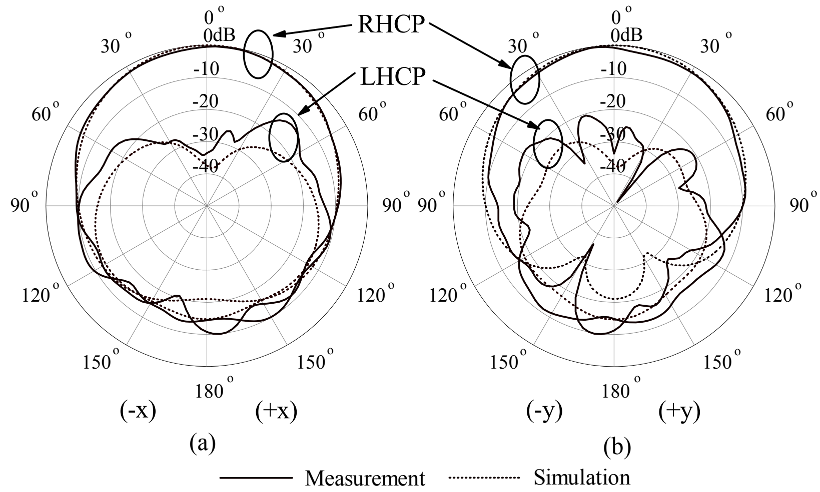

Figure 5: Measured and simulated radiation patterns at f=2.45GHz.
(a) x-z plane. (b) y-z plane.

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