Communications

A Low-Profile Compact Microwave Antenna With High Gain and Wide Bandwidth

Nasimuddin and Karu P. Esselle

***Abstract*—We demonstrate a low-profile, compact antenna consisting of a cross dielectric resonator on a microstrip patch and a quasi-planar surface mounted short horn (SMSH). The measurements show a 10 dB return loss bandwidth from 6.07 GHz to 7.52 GHz (21.3%) and a gain better than 9.0 dBi over this bandwidth. The total height of the antenna is only 8.61 mm and the aperture size is 48.1 mm × 43.1 mm. The cross-polarization level of the antenna at boresight is better than 28 dB in both E-and H-planes over the impedance bandwidth.**

***Index Terms*—Dielectric resonator antenna (DRA) , high gain, hybrid antenna, microstrip antenna, wide bandwidth.**

I. Introduction

Modern broadband communication systems and radars require lightweight compact antennas with high gain and wide bandwidth. Dielectric resonator antennas (DRAs) offer several advantages such as small size, ease of fabrication and high radiation efficiency. For example, a compact low-profile rectangular DRA can be designed to efficiently radiate either circularly or linearly polarized waves [1]–[4]. However, it suffers from low gain and a relatively narrow bandwidth. To achieve wide bandwidth, CRC researchers [5], [6] have proposed multi-segment DRAs and achieved impedance bandwidth up to 20%. Other wideband configurations include stacked DRAs excited by a coaxial probe, proposed by Kishk *et al.* [7], and hybrid dielectric-resonator-on-patch (DRoP) antennas proposed by Esselle and Bird [8], [9]. Several efforts have been made to increase the gain as well as the impedance bandwidth of DRAs. They include employing an offset dual-disk dielectric resonator (DR) [10], stacking parasitic DRs with an air gap between a main patch and parasitic DRs [11], and using composite layered DRs of high permittivity [12]. These efforts resulted in the gain improvements of up to 2.7 dB over a single DRA element. Hakkak and Ameri [13] have achieved a 7-dBi gain from a dielectric resonator loaded waveguide antenna with parasitic dielectric directors. However, in most cases the structures lack structural stability and are very large and therefore are not suitable for use in compact environments or as an array element. Recently, Adel [14] have used a surface mounted short horn (SMSH) to enhance the gain of a microstrip patch antenna. They have made a horn out of PVC sheet ($\epsilon_r = 3.38$) and mounted it around the patch structure. The inner surface of the horn is painted with the conductive silver epoxy. They have not studied the effects of the SMSH supporting material on radiation characteristics of antenna.

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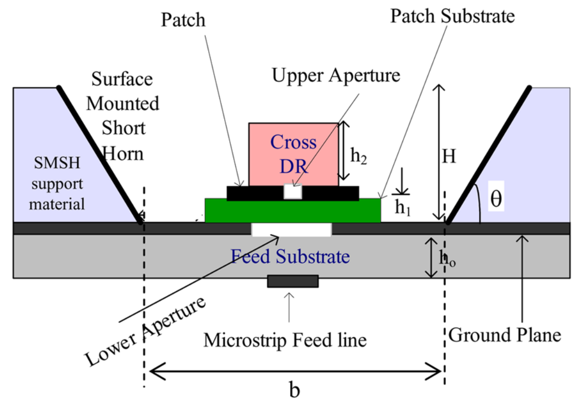

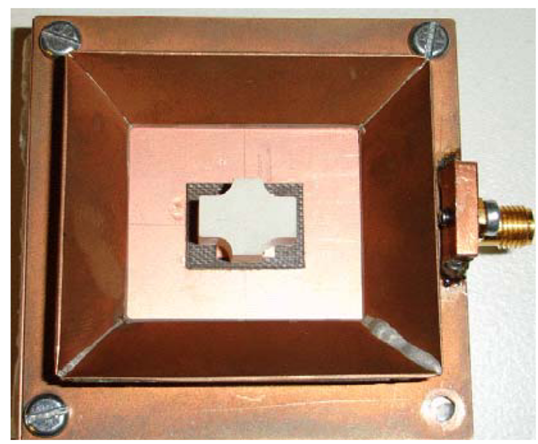

Fig. 1. (a) Cross DRA on patch with SMSH. (b) Photograph of a prototype.

In this letter, we propose to integrate a broadband hybrid DRoP element to a SMSH for gain and bandwidth enhancement. The particular hybrid element we present in this paper, shown in Fig. 1, consists of a cross DR aperture coupled to a microstrip patch. This element is coupled to a microstrip feedline using a second (lower) aperture. The proposed structure is mechanical stable, compact and easy to fabricate. In the proposed structure, the hybrid DR patch element acts as a feed to the surface mounted short horn. The theoretical results, obtained using Microwave Studio software [15], indicated an impedance bandwidth of 26% and a gain of more than 9.0 dBi over the impedance bandwidth. We have designed, fabricated and tested this antenna configuration and achieved a measured gain of more than 9 dBi over a 21.3% 10 dB return loss bandwidth.

II. Antenna Configuration and Design

The hybrid DRoP element, shown in Fig. 1, was first designed for wide impedance bandwidth and then integrated to SMSH for gain enhancement while maintaining the impedance bandwidth. Both stages of design have been carried out with the help of CST Microwave studio software. The DRoP has a wide impedance bandwidth due to two resonances, i.e., of the DR and the patch. These resonances occur at different frequencies and their combination gives a wider impedance bandwidth. Both the patch and the DR contribute to the

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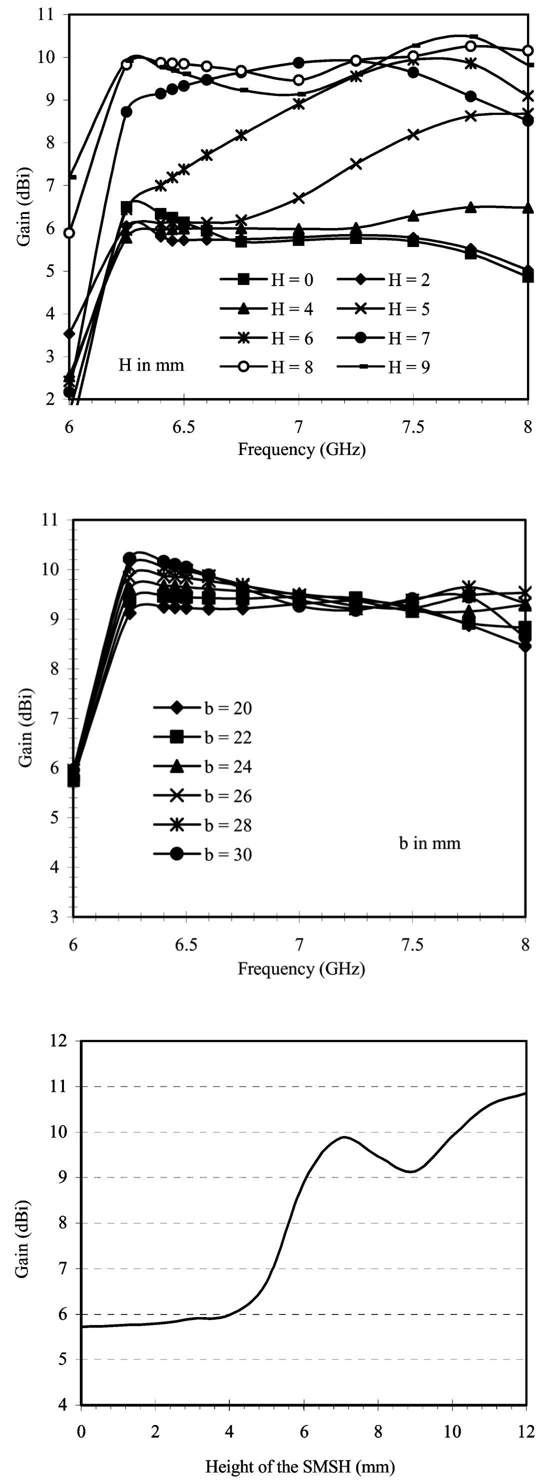

Fig. 2. (a) Gain variation with the height of the SMSH and frequency for $b = 27$ mm, $d = 32$ mm and $\theta = 45°$. (b) Gain variation with the SMSH length. Width of the SMSH $d = b + 5$ mm. (c) Theoretical gain of the antenna at 7 GHz.

radiation [9]. Depending on the design, the upper aperture in the hybrid element may also be designed to resonate and radiate, giving a further improved bandwidth but it was not attempted in the design presented here. Our main aim is to enhance the gain of the DRoP using SMSH while keeping the height of SMSH almost at the height of DRoP. The addition of the SMSH to the DRoP changes the return loss only slightly but the return loss bandwidth is almost the same.

TABLE I
DIMENSIONS OF THE ANTENNA

Structure	Dimensions
Feed microstrip line	Width = 1.16 mm, stub length = 2.6 mm h_o = 0.5 mm, ε_r = 3.38, tanδ = 0.0022
Lower coupling aperture	8.4 mm × 1.0 mm
Upper coupling aperture	7.2 mm × 0.7 mm
Patch substrate	h_1 = 0.76 mm, ε_r = 2.45, tanδ = 0.001
Patch	9.0 mm × 8.0 mm
Cross- DRA	Long arm: 12.8 mm × 6.0 mm Short arm: 10.4 mm × 5.0 mm h_2 = 6.35 mm, ε_r = 9.8, tanδ = 0.002
Surface mounted short horn	Base dimensions (b × d) = 27 mm × 32 mm Upper aperture = 48.1 mm × 43.1 mm Taper angle = 45°: height (H) = 8.1 mm

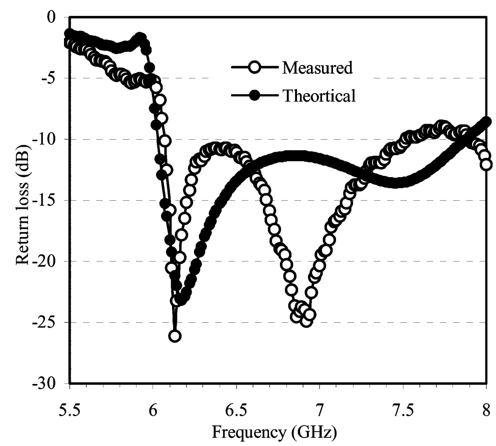

Fig. 3. Measured and theoretical return loss of the antenna.

First we fixed the SMSH base length (b) at 27 mm, base width (d) at 32 mm, and the taper angle (θ) at 45°. Then we analyzed the structure while changing the height of SMSH (H). The results, shown in Fig. 2(a), indicate that for H around 8 mm, the gain variation with frequency is low. Considering that the height of the DRoP element is 7.11 mm, we set H at 8.1 mm. For this value of H, we also studied the gain variation with SMSH length (b) and width (d). The results shown in Fig. 2(b) confirms that $b = 27$ mm, $d = 32$ mm is a reasonable choice, so the SMSH lateral dimensions were fixed at these values.

If the aim were to maximize mid-band gain, a different SMSH height would have been chosen. The gain at 7 GHz, plotted against the height of the SMSH in Fig. 2(c), indicates a maximum gain for a height of about 7 mm. The gain of the antenna increases drastically from $H = 5$ mm to $H = 7$ mm as the horn focusing effect establishes and the radiating aperture increases. At around $H = 7$ mm this monotonically increasing behavior stops apparently due to subtle variations in aperture efficiency.

A fabricated prototype is shown in Fig. 1(b) and dimensions of the antenna are shown in Table I. The SMSH was fabricated using the copper strips and mounted on the fabricated aperture coupled hybrid DR-on-patch (DRoP) element with help of metallic screws.

III. RESULTS AND DISCUSSIONS

The return loss of the prototype antenna, shown in Fig. 1(b), was measured using a HP 8720D Vector Network Analyzer. The measured and theoretical return loss of the antenna is shown in Fig. 3. The measured 10 dB return loss bandwidth is 21.3% (6.07 GHz–7.52 GHz),

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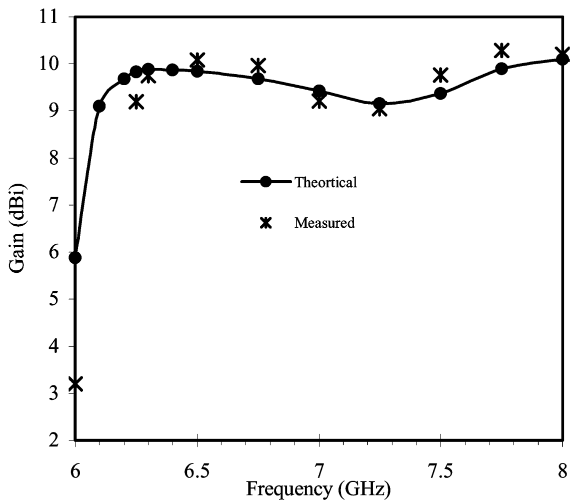

Fig. 4. Theoretical and measured gain of the antenna.

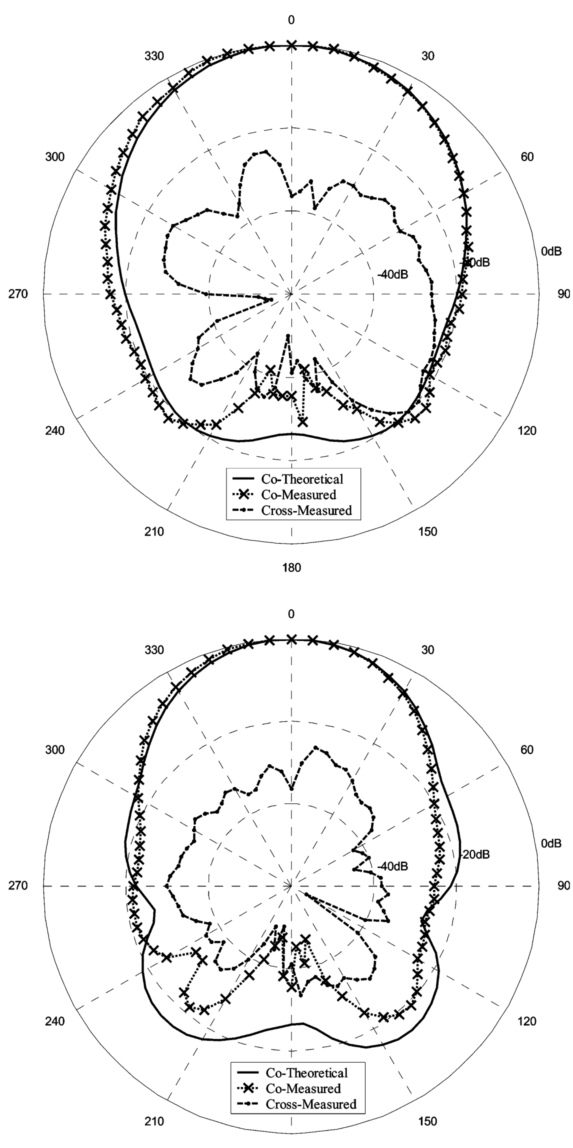

Fig. 5. (a) E-plane radiation pattern at 6.25 GHz. (b) H-plane radiation pattern at 6.25 GHz.

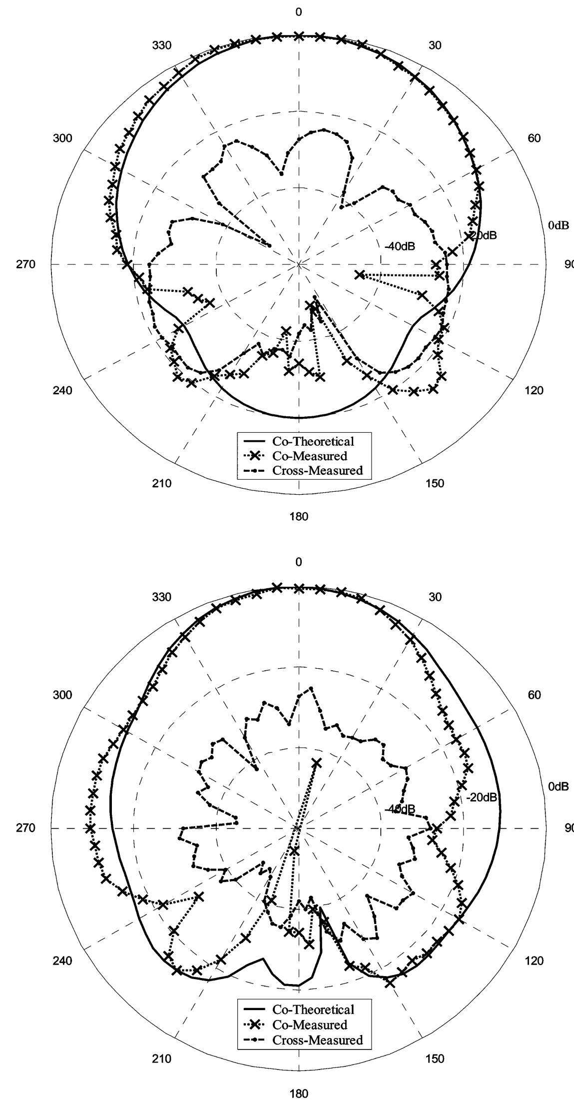

Fig. 6. (a) E-plane radiation pattern at 7.25 GHz. (b) H-plane radiation pattern at 7.25 GHz.

which is better than the conventional DRAs, and the theoretical bandwidth is 26% (6.03 GHz–7.88 GHz). The shift in the measured data, relative to the theoretical results, is due to fabrication and material imperfections and the effect of the glue used to mount the DRoP over the ground plane.

The gain and radiation patterns were measured in a NSI spherical near-field range and the gain is shown in Fig. 4. The measured gain is in excellent agreement with the theoretical gain, and it is more than 9.0 dBi within the 10 dB return loss bandwidth. We found that a cross DR on patch increases the gain by about 0.5 dB over a corresponding rectangular DR on patch.

The radiation patterns were measured at seven frequencies between 6.25 and 8.0 GHz and good agreement with theoretical patterns was observed for co-polarization over the main beam. For the sake of brevity, we present in Figs. 5 and 6 only the radiation patterns at 6.25 and 7.25 GHz, respectively. The both theoretical and measured radiation patterns are in very good agreement.

We noted that the addition of the SMSH to the DRoP also improved the back lobe level by about 5 dB. We also found that SMSH made out of copper strips has a higher gain than a SMSH made out of a copper block [16] or a PVC block [14].

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IV. Conclusion

We have been able to achieve high gain over a wide impedance bandwidth by integrating a cross-DR-based hybrid DRoP element with a surface mounted short horn. By selecting the height and lateral dimensions of the SMSH appropriately, the variation of the antenna gain over the impedance bandwidth can be reduced. The use of a cross DR instead of a rectangular DR contributed to an extra 0.5 dB increases in gain.

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A Novel Planar Switched Parasitic Array Antenna With Steered Conical Pattern

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***Abstract*—A novel planar switched parasitic array antenna has been proposed for wireless communication. Compared with conventional switched array antennas, this array antenna has more compact planar structure and steered conical elevation pattern. Simulation and measurement have been carried out to validate the design. PIN diodes and micro-controller unit (MCU) are used to implement a beam switching system. Experimental results show that this antenna has the capacity to provide beam switching.**

***Index Terms*—Conical pattern, parasitic array, switched antenna.**

I. Introduction

Switched parasitic array antennas have been studied extensively recently [1]–[6], due to their advantages of improving the capacity of wireless communication system and reducing the interference from neighboring users in the same cell area. Different from an adaptive array, a switched parasitic array antenna has a single RF channel without any other tunable component in the RF channel, i.e., all the switches are located on the parasitic elements. Hence, switched parasitic array antennas should be low cost and more robust [7], and more suitable for mobile terminals than switched active array antenna.

Since the existing switched parasitic array antennas are commonly based on monopoles, the profile of the whole structure brings much difficulty for integration into mobile terminals. Thiel [2] used microstrip patch antenna elements to form an array. However, the main beam of general microstrip antennas is directed toward broadside not endfire, which limits its employment for wireless access systems.

Aiming for a compact planar antenna structure and conical elevation pattern, we first adopted a modified central grounded patch element [8] for concept validation [9]. The array has small size and the desired conical radiation pattern in elevation. The hexagonal configuration makes the array more compact and results in higher gain accordingly. Recently, Shi [10] used a similar structure to form a switched array antenna. However, the radiation pattern of this antenna is still directed to the broad side, since the two feeding points are used to realize circular polarization instead of shorting post in the center of antenna patch.

Based on the previous work [9], we integrate the control system and the antenna part together to implement a real switched parasitic array antenna in this paper, where PIN diodes and the MCU control system are used to realize the control system. In this demo system, the MCU could receive the control signal from a PC via the RS232 interface, then change the status of each parasitic element.

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