60-GHZ CPW-FED DIELECTRIC-RESONATOR-ABOVE-PATCH (DRAP) ANTENNA FOR BROADBAND WLAN APPLICATIONS USING MICROMACHINING TECHNOLOGY

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ABSTRACT: *A 60-GHz coplanar waveguide (CPW)-fed dielectric-resonator-above-patch (DRAP) antenna using micromachining technology is presented. In the proposed structure, the patch is elevated in the air with support of a dielectric-post, and a rectangular dielectric resonator antenna (RDRA) is fixed above the patch. The size of the RDR is 1 × 0.8 mm^2. We introduce a novel use of micromachining technology (solder ball bumping and flip chip bonding) for the first time to exactingly align and bond a small RDRA with a feed-slot. The fabricated antenna shows broadband characteristics such as −10-dB bandwidth of 17.5 GHz from 54 to 71.5 GHz, corresponding to a fractional bandwidth of 29.2%. Moreover, the radiation pattern could be measured by integrating the proposed antenna with a 60-GHz VCO. An antenna gain of about 3.6 dBi at 60 GHz is measured.* Microwave Opt Technol Lett 49: 1859–1861, 2007; DOI 10.1002/mop.22632

Key words: *CPW-fed dielectric resonator above patch (DRAP) antenna; micromachined antenna; 60-GHz broadband WLAN antenna; antenna integrated with 60-GHz VCO*

1. INTRODUCTION

THE wideband millimeter-wave frequency spectrum around 60 GHz is of special interest for high data rate wireless local area network (WLAN) since tremendous bandwidth up to 8 GHz is available there [1, 2]. Horn antennas are generally used at the mm-wave frequencies due to their high performance, but it is very bulky, heavy, and high cost. Moreover, the transition of waveguide-to-microstrip transition is needed to interconnect with monolithic microwave integrated circuits (MMICs) [3]. Microstrip patch antennas built on printed circuit board (PCB) substrate, are attractive due to their various features like, light weight, low cost, easy of fabrication, and so on. However, the microstrip element suffers from the inherent limitation of narrow impedance bandwidth and poor performance due to high substrate losses and low radiation efficiency at mm-wave frequencies [4]. Thus, microstrip antennas are not well suited to broadband wireless applications at mm-wave frequencies. Dielectric resonator antennas (DRAs) are increasingly employed in antenna applications due to favorable properties such as inherently wide bandwidth, small size, and high efficiency. Conductors and surface wave losses are absent from DRAs, and the bandwidth of these antennas may be improved without compromises in efficiency and other positive characteristics [5, 6]. In such antennas, the thickness of the substrate may not be more than one quarter guided wavelength because surface wave losses occur thereafter. Also, the reflection coefficient changes seriously due to alignment variation between the ceramic body and feed-structure [7]. So, the fabrication of DRAs at mm-wave frequencies by using the previous technology is very difficult due to its small size.

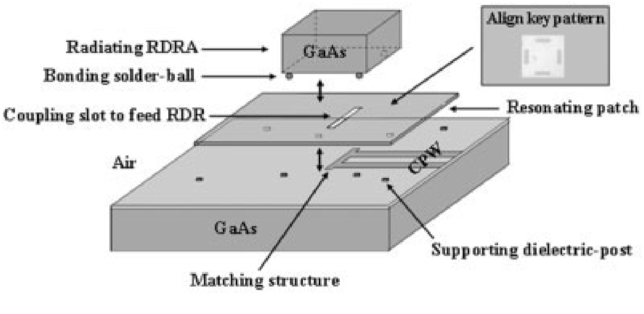

Figure 1 Proposed CPW-fed DRAP antenna

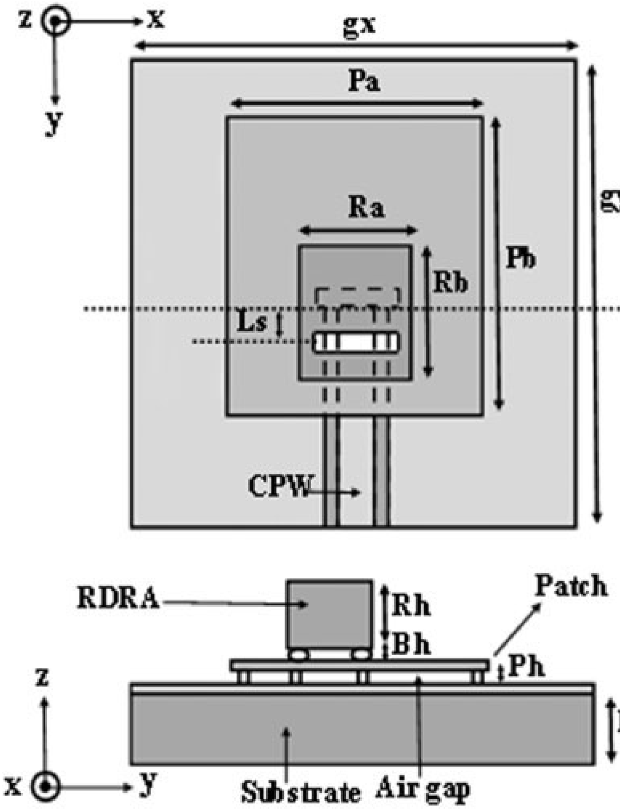

Figure 2 Top view and side view of the proposed antenna structure

To reduce dielectric loss in the conventional microstrip transmission line, several groups have recently researched the low-loss transmission line using micromachining technology. To achieve low losses over the wide impedance range, the dielectric-supported air gapped microstrip line (DAML) structure is developed using GaAs-based surface micromachining techniques with an air-bridge connection between the signal lines, [8]. Meanwhile, micromachining technologies such as laser dicing make possible the processing of small dielectric structures. Especially, high resolution of alignment between chips and wafers has been made possible through the use of micromachining technologies such as solder ball bumping and flip chip bonding [9].

This letter presents a CPW-fed dielectric resonator above patch (DRAP) antenna fabricated by micromachining technology for

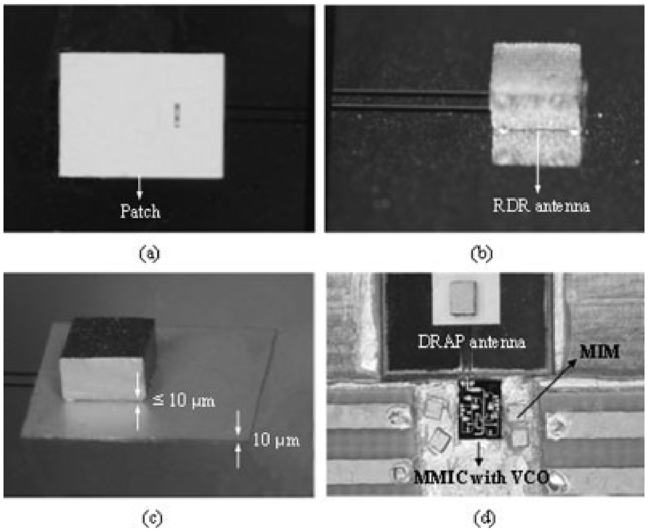

Figure 3 (a) The patch supported by dielectric post, (b) 60-GHz RDRA, (c) the proposed antenna, and (d) the antenna integrated by 60-GHz VCO

broadband wireless applications at the mm-wave frequency of 60 GHz. Moreover, due to the inclusion of an air-gap, the proposed antenna could be designed on thick substrate (= 680 μm ≈ 0.45 λg).

2. DESIGN OF THE PROPOSED ANTENNA

The proposed antenna is designed and optimized with a commercial EM simulator of CST Microwave Studio 5.1. Figure 1 shows the structure of the CPW-fed DRAP antenna. As shown in Figure 1, the antenna comprises a CPW feed line, supporting dielectric-posts, a resonating patch, and a radiating rectangular dielectric resonator. The structure of the proposed antenna is similar to that of the DROP antenna [5], but the patch of proposed structure is elevated by 10-μm dielectric-posts and fed by the CPW line. Because of the small air-gap afforded by the posts, the patch operates not as a radiator but as a high-Q resonator. The RDRA is fixed above the patch. In the former sentence “above” means that use of a bonding solder-ball between the RDRA and patch affords additional air-gap of 10 μm. The RDRA is fed through the rectangular slot of the patch. The patch and RDRA are designed to resonate at 60 GHz. As shown in Figure 4, each of them has narrow bandwidth due to high-Q property, but combining two elements causes coupling between the patch and RDRA, and lower and upper resonant frequencies to be split, thus resulting in a wide bandwidth such as a −10-dB fractional bandwidth of 29.2%. Generally, the dielectric constant of DR antennas must be much higher than that of the substrate to obtain high radiation efficiency ($\varepsilon_r \geq 20$) [10]. However, in the proposed antenna, the RDRA and substrate may have the same dielectric constant ($\varepsilon_r \approx 12.9$) due to the air-gap ($\varepsilon_r \approx 1$) in the feeding structure.

Figure 2 shows design parameters of the proposed antenna. It is known that $R_a = 0.8$ mm, $R_b = 1$ mm, and $R_h = 0.68$ mm of RDRA can be approximately determined for the resonant frequency of the TE111-mode [10]. The patch size is $P_a = 2.4$ mm, $P_b = 2.6$ mm which is about half of one wavelength in the air. The other parameters are fixed as $h = 0.68$ mm, $g_x = g_y = 6$ mm, $P_h = 10$ μm, $B_h \leq 10$ μm, $L_s = 0.39$ mm. The offset distance L_s between the center of the RDRA and the rectangular slot of the patch is a major design parameter of the antenna. As determined in [7], varying the offset distance L_s significantly influences input impedence matching. Thus, processing must be conducted with high accuracy.

3. FABRICATION OF THE ANTENNA

The patch is elevated by 10-μm polymide dielectric post and is overlapped with the ground plane by using DAML’s structure. This structure is advantageous as it reduces the dielectric loss of the substrate, since most of the electric field is confined in the air

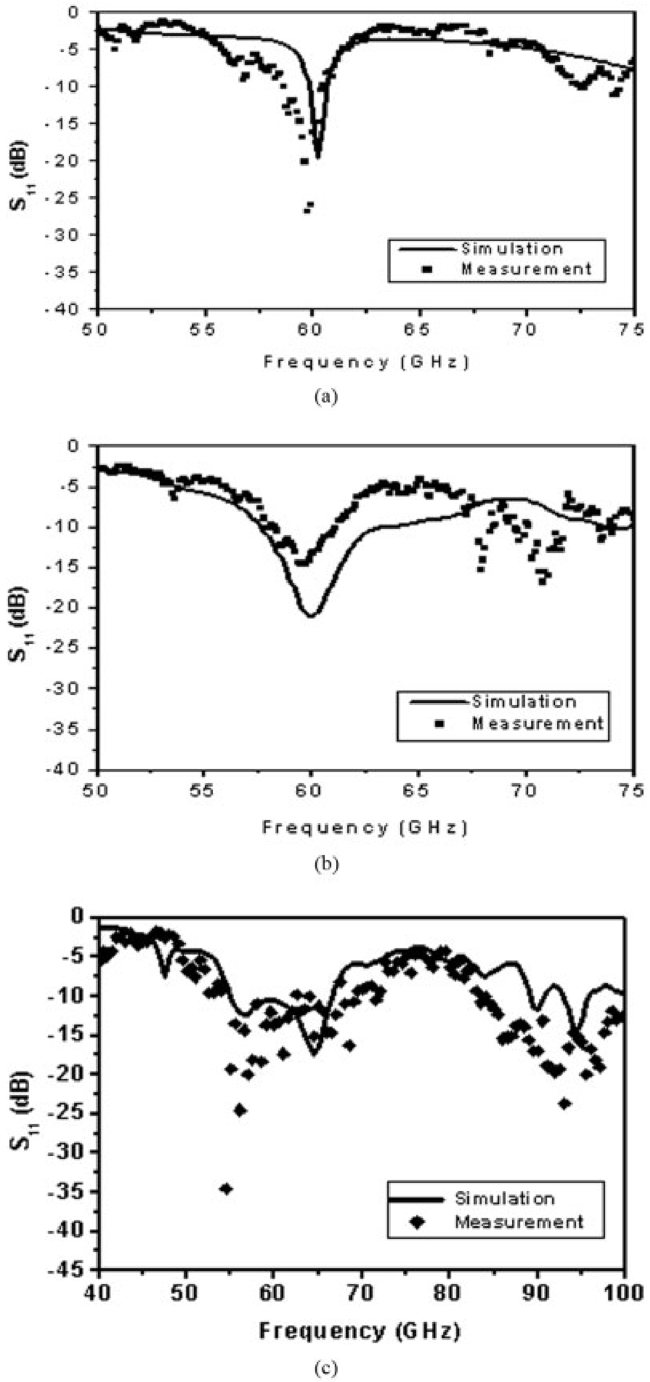

Figure 4 (a) Measured and simulated input return loss of the patch supported by dielectric post, (b) measured and simulated input return loss of 60-GHz RDR antenna, and (c) measured and simulated input return loss of proposed antenna

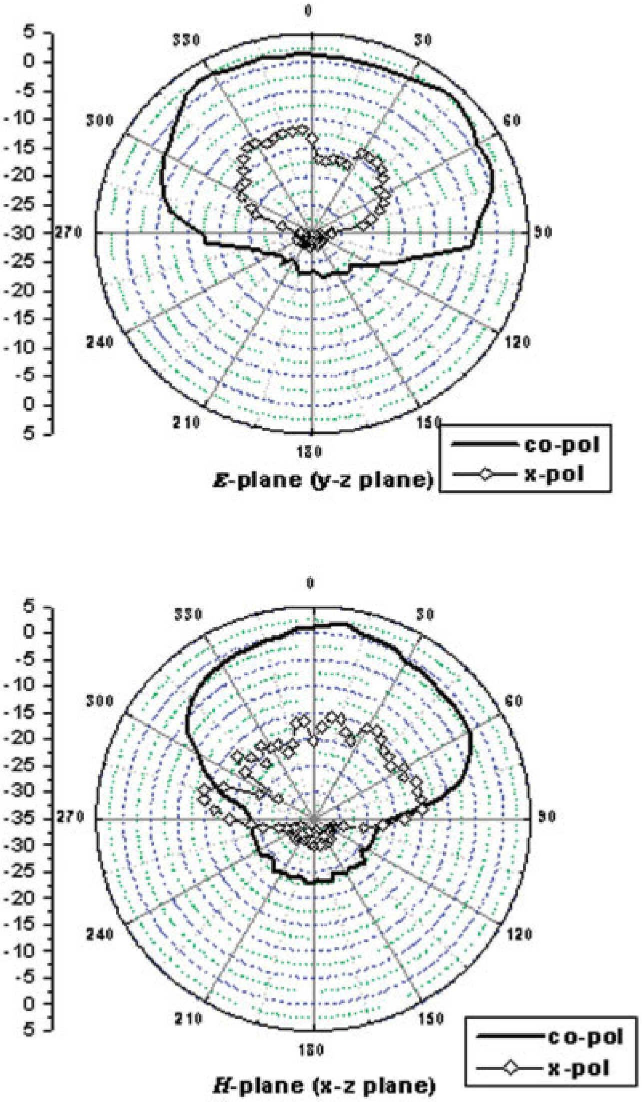

Figure 5 Measured *E*-plane and *H*-plane antenna radiation patterns at 60 GHz. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

region between the patch and the ground [8]. Recently, advances in dicing technology, such as the use of laser dicing and newly designed blades, allow wafers to be diced with high accuracy and minimum mechanical damage to the dice [11]. Using such novel technology, we can fabricate RDRAs with the size of about 1 mm. Solder ball bumping is used to align the bonding ball to the key pattern formerly etched in the patch. By searching for the position of the bonded ball on the patch, flip chip bonding allows exacting alignment of the RDRA with the patch. Figure 3(c) shows a picture of the fabricated antenna.

4. MEASUREMENT RESULTS

Figure 4 shows the simulated and measured results of input return losses of the patch, RDRA and proposed antenna. The patch and RDRA results include narrowband characteristics of 10-dB bandwidth of 1.8 and 3.5 GHz, corresponding to a relative bandwidth of 3 and 5.8%, respectively. However, the proposed antenna has a bandwidth of 29.2% and is in the frequency range of 54–71.5 GHz. On the whole, all of the measurement results agree with those of the simulation.

Figure 3(d) shows the proposed antenna fed by 60-GHz VCO to measure radiation patterns. Figure 5 shows the measured antenna radiation patterns at 60 GHz. Antenna radiation patterns are broadside and unidirectional in both the *E*-plane and *H*-plane. An antenna gain of about 3.6 dBi at 60 GHz is achieved and the cross-pol levels were at least 12 dB lower than the co-pol levels.

5. CONCLUSION

A 60-GHz CPW-fed dielectric-resonator-above-patch antenna (DRAP) using micromachining is presented for broadband WLAN applications. We applied micromachining technology (solder ball bumping and flip chip bonding) to, for the first time, fabricate a small rectangular dielectric resonator antenna (RDRA) and integrated this antenna with MMICs. This antenna can be used for applications requiring thick substrate such as LTCC and the system on a chip (SOC) at mm-wave frequencies.

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