Stripline-fed aperture-coupled patch array antenna with reduced sidelobe

Yonghun Cheon✉ and Yonghoon Kim

An aperture-coupled patch array antenna with a reduced sidelobe level (SLL) at the 28 GHz frequency band is presented. The feeding line consists of an asymmetric stripline with a stripline-to-waveguide transition. The array antenna is serially fed in the *E*-plane, the excitation of which is tapered by controlling the aperture sizes, and is fed through a power divider in the *H*-plane. The experimental results show a SLL of <−20 dB and a gain of ~20 dBi for a frequency band in the range of 27.5–28.5 GHz.

Introduction: Microstrip antennas have been widely used in various areas of industry owing to their superiority in terms of light weight, low profile, low cost, and ease of fabrication. However, there are considerations to be taken into account to achieve low sidelobe level (SLL) performance, such as amplitude and phase accuracies, radiation from feed networks, and fabrication tolerances [1]. Many studies have been devoted to lower the SLL of series-fed array antennas, such as by controlling the width of patches to shape the aperture distribution, by using a coupled feed line for a microstrip line feed, and by displacing slots axially for a slot array antenna [2–4].

In this Letter, an aperture-coupled microstrip array antenna is designed and evaluated to enhance SLL performance by controlling the excitations of each patch through varying the size of coupling apertures along the *E*-plane, and by power dividing with the Dolph-Chebyshev distribution for −23 dB SLL along the *H*-plane. The array is fed by a stripline with shorting vias around each aperture to eliminate parasitic modes caused by the apertures [5].

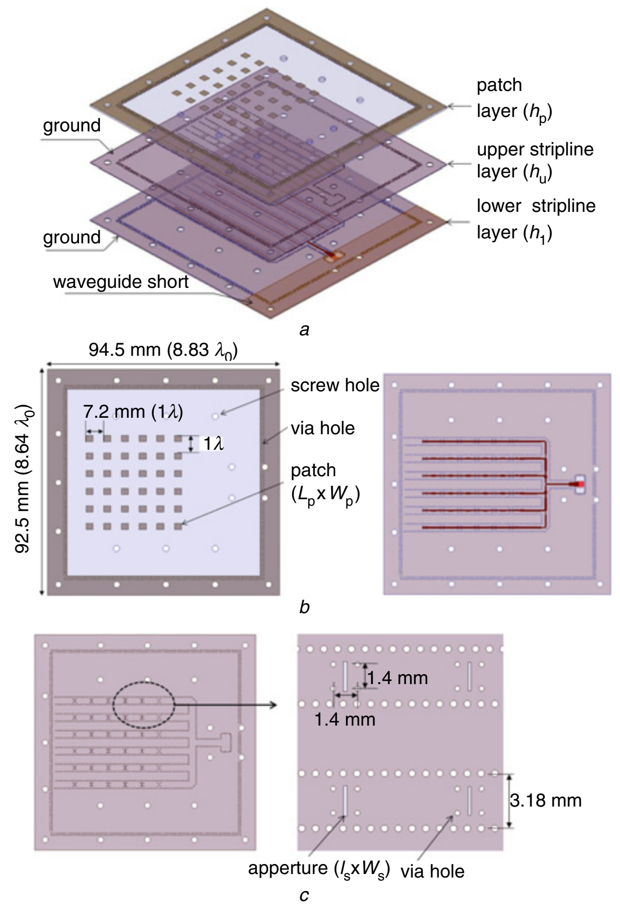

Fig. 1 *Geometry of proposed array antenna*

a Perspective view ($h_p = 0.76$ mm, $h_u = 0.25$ mm, $h_l = 0.51$ mm)
b Patch layer (left, $L_p = 2.85$ mm, $W_p = 2.5$ mm, λ_0 = wavelength in the free space at 28 GHz); (right, lower stripline layer)
c Upper stripline layer

Table 1: Aperture sizes for tapered excitation

Aperture size	1st, 6th apertures	2nd, 5th apertures	3rd, 4th apertures
$ls \times ws$ (mm^2)	1.2 × 0.1	1.65 × 0.16	1.75 × 0.22

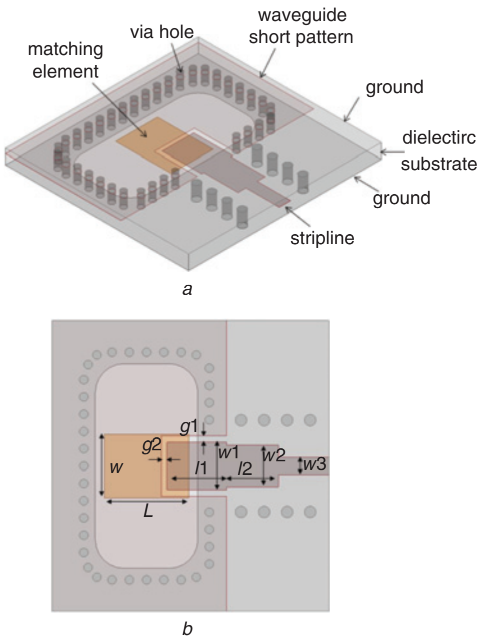

Fig. 2 *Geometry of stripline-to-waveguide transition*

a Perspective view
b Top view ($L = 2.92$ mm, $W = 2.2$ mm, $g1 = 0.23$ mm, $g2 = 0.18$ mm, $l1 = 2.07$ mm, $w1 = 1.65$ mm, $l2 = 1.8$ mm, $w2 = 1.43$ mm, $w3 = 0.6$ mm)

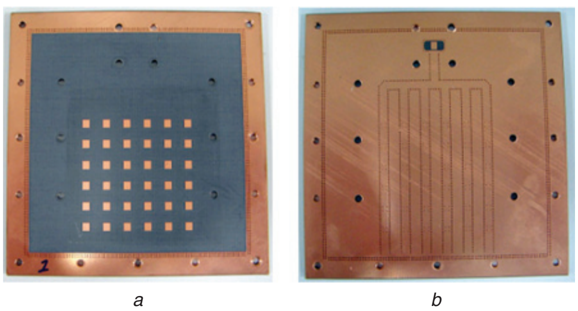

Fig. 3 *Fabricated 6 × 6 array antenna*

a Top view
b Bottom view

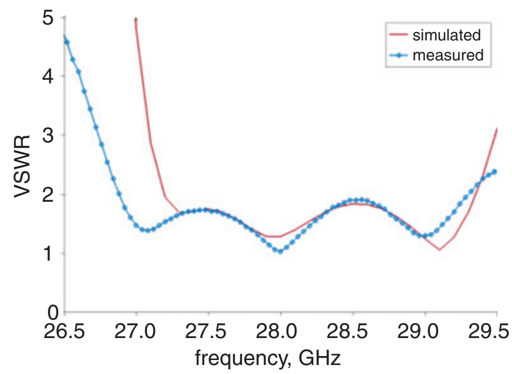

Fig. 4 *Measured and simulated results of VSWR*

Proposed antenna: The proposed array antenna consisted of the patch layer, upper stripline layer, and the lower stripline layer as shown in Fig. 1. The layers are fabricated by Taconic TLY substrates with $\varepsilon_r = 2.2$ and $\tan\delta = 0.0009$. The stripline has an asymmetric structure with different substrate thicknesses to support the microstrip line field-like distribution. The array antenna has a uniform patch size and uniform separation between patches of 7.2 mm = 1λ, where λ is the wavelength at 28 GHz in the substrate. Along the *E*-plane, the excitations of each patch are controlled by varying the size of the apertures as listed in Table 1. Four shorting vias are implemented around each aperture with a diameter of 0.3 mm and the sidewall vias are constructed along the stripline with a distance of 3.18 mm (0.44λ) to avoid higher-order modes. On the lower stripline layer, a stripline-to-waveguide transition is realised and the geometry of the transition is shown in Fig. 2 [6].

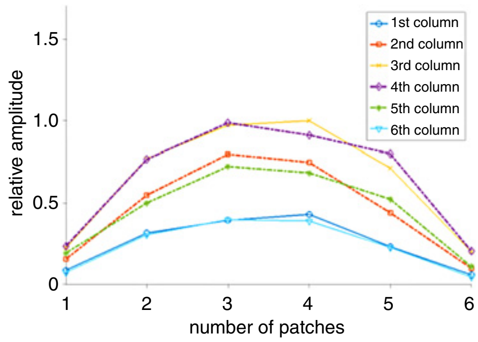

Fig. 5 *Simulated electric field intensity over the patches*

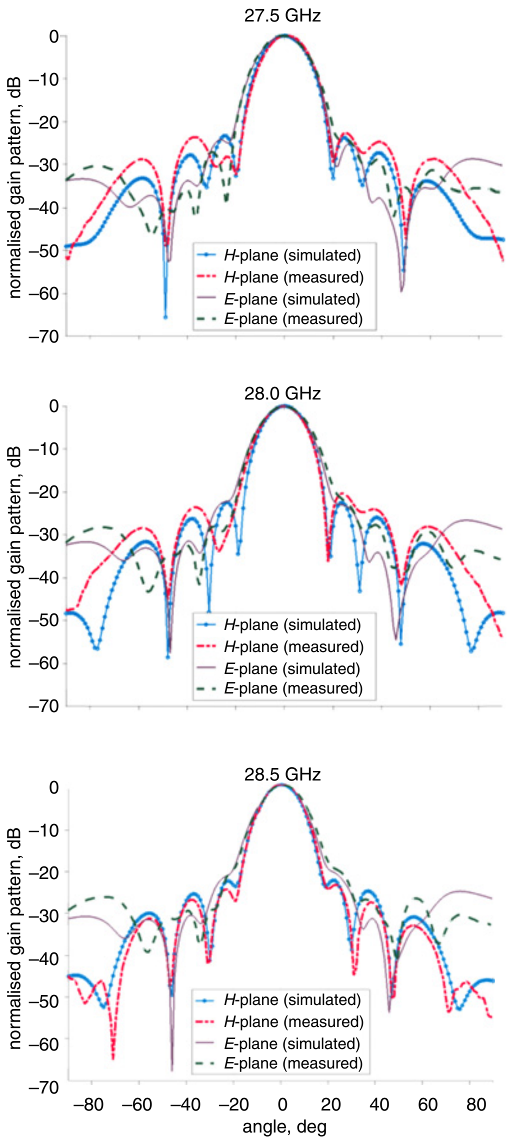

Fig. 6 *Normalised radiation patterns at 27.5, 28.0, and 28.5 GHz*

Simulated and measured results: The proposed design for the low SLL 6 × 6 array antenna was verified from simulations and measurements of the VSWR and radiation characteristics. The simulation was performed using the Ansoft HFSS software. The stripline-to-waveguide transition has a return loss of <−17 dB and an insertion loss of <0.15 dB for the frequency band range of 27.5–28.5 GHz in the simulations. The photographs of the fabricated array antenna are shown in Fig. 3. The measured and simulated results of the VSWR are shown in Fig. 4 and the measured impedance bandwidth (VSWR < 2) is 2.5 GHz (26.8–29.3 GHz). Simulated electric field intensities over the patches are shown in Fig. 5 and the tapered excitations are realised by controlling the aperture size.

The radiation characteristics of the fabricated array antennas were measured in an anechoic chamber and the results are depicted in Fig. 6 and Table 2. The measured gain is less than the simulated, which might be caused by less power coupled to patches due to the varying aperture sizes. The measured HPBWs are close to the simulated. The SLLs are <−20 dB.

Table 2: Radiation characteristics of array antenna

Frequency (GHz)		Gain (dBi)	HPBW (deg) (*H*-plane/*E*-plane)	SLL (dB) (*H*-plane/*E*-plane)
27.5	Simulated	21.5	15.3/16.3	−23.3/−24.2
	Measured	19.6	15.3/16.7	−22.6/−23.9
28.0	Simulated	21.6	14.8/15.9	−22.4/−22.4
	Measured	20.2	14.9/16.4	−20.3/−22.1
28.5	Simulated	21.6	14.6/15.8	−22/−20
	Measured	20.3	15.3/16.1	−23.1/−20

Conclusion: A method of reducing SLL for a stripline-fed aperture-coupled array antenna is proposed. The excitations are controlled by varying the sizes of the apertures along the *E*-plane and the power divider along the *H*-plane. The measured results of the fabricated 6 × 6 array antenna demonstrated reduced SLLs of <−20 dB.

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One or more of the Figures in this Letter are available in colour online.

Yonghun Cheon and Yonghoon Kim (*DMC R&D Centre, Samsung Electronics Co. Ltd, Suwon 443-742, Republic of Korea*)

✉ E-mail: yh92.cheon@samsung.com

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