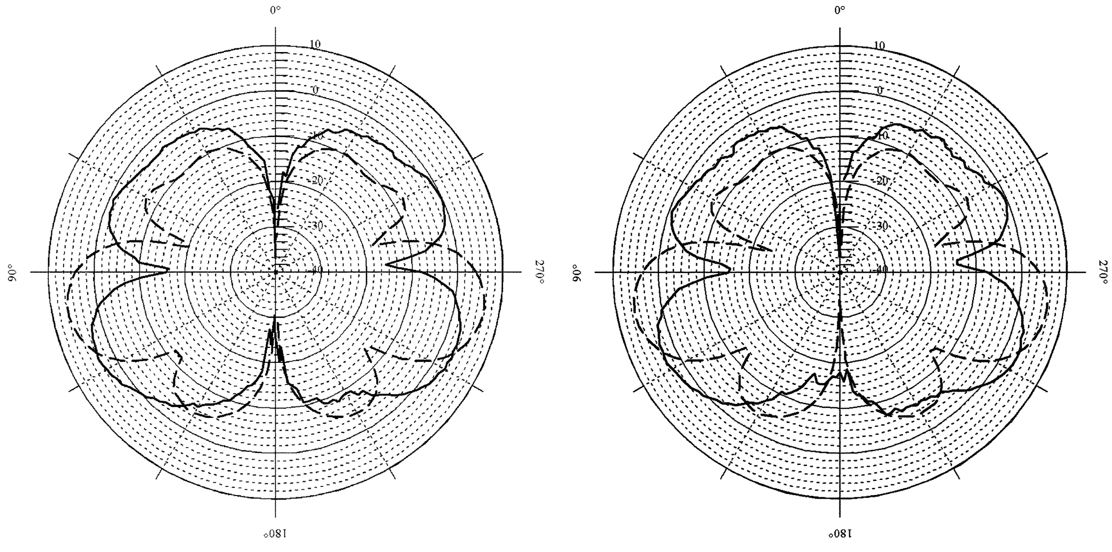

(a)

(b)

Fig. 4. (a) y–z plane radiation patterns of OMA computed using FDTD analysis (dashed) and measured (solid) 2.215 GHz. (b) x–y plane radiation patterns of OMA computed using FDTD analysis (dashed) and measured (solid) 2.215 GHz.

IV. CONCLUSION

An omnidirectional microstrip antenna was described which can be scaled to control its gain properties and has a very omnidirectional pattern. The fabrication process is simple and low cost.

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Broad-Band Double-Layered Coplanar Patch Antennas With Adjustable CPW Feeding Structure

K. F. Tong, K. Li, T. Matsui, and M. Izutsu

***Abstract*—In this paper, we have presented the double-layered coplanar patch antennas of enhanced impedance bandwidth and adjustable conductor-backed coplanar waveguide feed lines. The proposed structure retains the advantage of laying the coplanar patch and coplanar waveguide (CPW) feed line on the same surface, which makes direct integration with other devices easier. In addition, the substrate thickness of the radiating patch can be adjusted to achieve a wider impedance bandwidth while the dimensions of the CPW feed line are kept unchanged. Simulation has been done by using commercial electromagnetic (EM) simulation software. Four testing antennas, which have centre frequency at about 10 GHz, were designed. The four testing antennas had the same total thickness, but different thickness combinations. From the measured return loss, gain, and radiation patterns of the antennas, it was demonstrated that different thickness combinations do not affect the characteristics of the antennas seriously. Therefore, the dimensions of the CPW feed structure of the antennas can be adjusted individually and can be selected for different applications.**

***Index Terms*—Broad-band antenna, coplanar waveguides feed line, planar antenna.**

I. INTRODUCTION

Coplanar waveguide (CPW) fed antennas [1]–[6] have advantages such as low radiation loss, less dispersion and uni-planar config-

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The authors are with the National Institute of Information and Communications Technology, Tokyo 184-8795, Japan (e-mail: kenneth@nict.go.jp).

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uration. Moreover, the input of the antennas can directly connect to the CPW outputs of semiconductor device circuits. This feature provides much convenience in system integration, especially in millimeter wave applications. Coplanar patch antennas (CPAs), which enjoy the above advantages, have been proposed in [7], [8]. The geometry of a coplanar patch antenna looks like a loop slot antenna with a ground plane. However, as indicated by the simulated and experimental results, the CPAs behave more like a microstrip patch antenna than a loop slot antenna, for example, the resonant frequency of the CPA is determined by the patch length, which is approximately equal to half of a guided wavelength, and not by the perimeter of the slot [7]. Additionally, coplanar patch antennas inherit another characteristic of microstrip patch antennas-narrow impedance bandwidth (return loss < -10 dB). It is only a few percentages (about 3.4%), which may be inadequate for communication systems nowadays.

As we have confirmed the resonant mechanism of a CPA is similar to that of a microstrip patch [7], it can be predicted that the bandwidth of the antenna can be widened simply by increasing the thickness of the dielectric substrate. However, if we want to retain the advantage of keeping the feed line and the radiation patch on the same surface, we have to increase the substrate thickness of the feed line as well. This will result in a problem that the dimensions of the CPW feed line may be impractical for real applications. For example, if we want to design a CPA, which will operate at about 10 GHz and have an impedance bandwidth of about 10%, the thickness of the dielectric substrate $(\varepsilon_r = 2.17)$ will be about 2.032 mm. Moreover, the slots and centre conductor of the $50\ \Omega$ conductor-backed coplanar waveguide (CBCPW) feed line will be 0.7 and 4.8 mm, respectively. However, the diameter of dielectric core of a conventional SMA connector is only about 4.5 mm. It will be difficult to connect the antennas and the connectors without shorting the ground and centre conductor.

In this article, we have investigated a new kind of double-layered geometry that can increase the impedance bandwidth of the antennas and provide flexibility in the dimensions of the CPW feed lines at the same time. The double-layered structure allows the coplanar patch and CBCPW feed line to have different layer thickness. This advantage keeps the thickness of the CBCPW feed line thin, i.e., reduces the center strip conductor width to the total CBCPW feed line width ratio (R_{ws}), which equal $(w_f/(w_f + 2s_f))$ as shown in Table I and minimizes the dispersion of the transmission line. On the other hand, it does not limit the layer thickness of the coplanar patch, so a wider impedance bandwidth can be achieved. Moreover, we can retain the uni-planar structure of the feed line and patch surface.

Then we continued the investigation to the characteristics of the CPAs that consist of different layer thickness combinations. The total thickness of the antennas was kept unchanged. The variations of the thickness combination provide convenience for circuit integrations, as the ratio R_{ws} can be controlled by changing the thickness of upper layer (h_1). Simulation was done by the commercial package Ansoft Ensemble.

The design of a broad-band double-layered coplanar patch antenna is first based on the single-layered structure, which can satisfy the design requirement, such as impedance bandwidth, gain and radiation patterns. Then we insert the middle layer ground plane and adjust the subtract thickness under the CBCPW feed line (h_1), until the desired size of the slot widths and centre conductor strip width of the CBCPW for integration are achieved. Finally, we will fine-tune the other parameters to obtain the best matching.

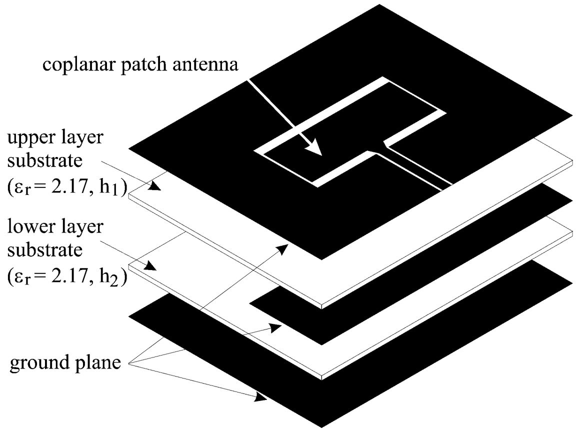


Fig. 1. Geometry of broad-band double-layered coplanar patch antenna.

II. Antenna Geometry and Design

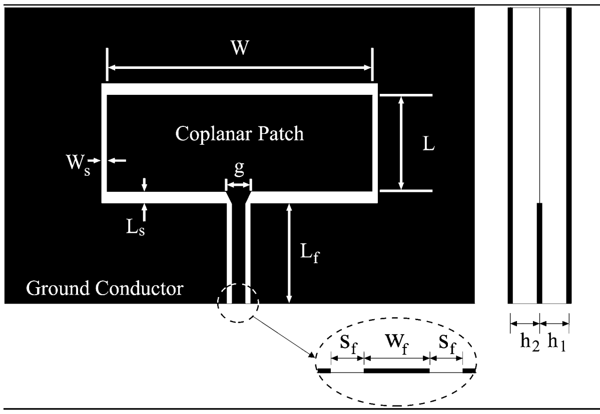
The geometry of a broad-band double-layered CPA is shown in Fig. 1. The antenna is composed of two layers of DICLAD 880 dielectric substrate of relative permittivity equal to 2.17 and loss tangent equal to 0.00085 at 10 GHz. The thicknesses of the upper and lower layers are denoted as h_1 and h_2, respectively. A coplanar patch is located on the top of the upper layer. Energy from the input is fed to the coplanar patch thru the conductor-backed coplanar waveguide (CBCPW) connected to one of the radiating edges. Between the two substrates, there is a copper layer. The length of this middle copper layer equals the length of the feed line (L_f). The primary role of this copper layer is to provide a ground plane for the CBCPW feed line, so the thickness of the feed line (h_1) can be different from that of the coplanar patch $(h_1 + h_2)$. Moreover, the antenna retains its own uni-planar structure. The impedance of a CBCPW transmission line is determined by the substrate thickness (h_1), the slot width (s_f) and the center conductor strip width (w_s) [9]. Therefore, for a particular line impedance, we can control the ratio R_{ws} by changing the thickness of the upper layer. At the back of the lower layer, there is the third ground plane, which is the ground plane of the coplanar patch. The top, middle, and bottom ground planes are connected by the left and right side walls of the antennas.

Four test antennas (AUT A to D) were designed and fabricated. The total thickness $(h_1 + h_2)$ of the four antennas is all kept to 1.016 mm, and impedance bandwidths ($|S_{11}| < -10$ dB) of the antennas will be about 8.5%. The layer thickness combinations of AUT A to D are $(0.254 + 0.762)$, $(0.508 + 0.508)$, $(0.762 + 0.254)$, and $(1.016 + 0)$ mm, respectively. The other dimensions of the double-layered CPAs were tabulated in Table I.

III. Results and Discussion

The measured return losses of the four test antennas are shown in Fig. 2. The resonant frequencies of the antennas are about 10.0 GHz. The impedance bandwidths are about 8.5%. The return loss of an ordinary single-layered coplanar patch antenna is also shown for comparison. We can see that the bandwidths of the double-layered designs are about twice as large as the ordinary single-layered one.

TABLE I
DIMENSIONS OF THE BROADBAND DOUBLE-LAYERED CPAS (IN MILLIMETERS)



parameter	AUT A	AUT B	AUT C	AUT D
$h = h_1+h_2$	0.254 + 0.762	0.508 + 0.508	0.762 + 0.254	1.016 + 0.0 (single-layered)
s_f-w_f-s_f	0.2-0.7-0.2	0.2-1.3-0.2	0.2-1.7-0.2	0.2-2.1-0.2
W, L	30, 9.6	30, 9.6	30, 9.6	28, 9.1
W_s, L_s	0.5, 2.0	0.5, 2.0	0.5, 2.0	0.5, 2.0
L_f	17.0	17.0	17.0	17.0
g	3.8	3.8	3.8	3.8

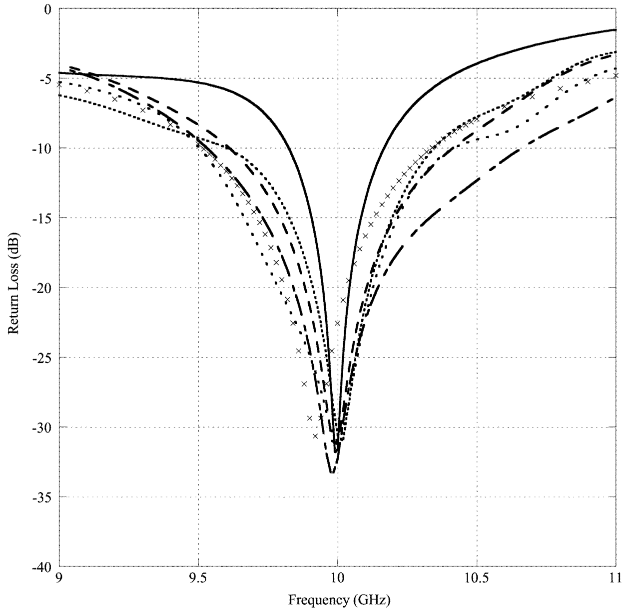


Fig. 2. Return loss of the double-layered CPA. ——— original single-layered CPA, × × × × × simulation result of AUT B, - - - - - - - - measurement result of AUT A, - - - - - - - measurement result of AUT B, ———— measurement result of AUT C, - - - - - - - - measurement result of AUT D.

From Fig. 2, it is apparent that the simulated and measured results for the resonant frequency and impedance bandwidth of AUT B are within 0.8% and 9%, respectively. These deviations are considered reasonable Fig. 3 shows the gains of the antennas. For AUT A, B, and C, a maximum gain of 9.4 dBi is obtained at 10.0 GHz. The gain of AUT D is 0.4 dBi higher than that of other three antennas under test.

The radiation patterns of the antennas at 10 GHz are shown in Fig. 4. The half-power beamwidths of the antennas are about 40° and 67° in H-plane and E-plane, respectively. The cross-polarization levels are less than − 18 dB in both planes. The slightly higher cross-polarization in the double-layer structures may be caused by the thickness change at the feed points. The asymmetry of E-plane radiation patterns are caused by the connectors and the CBCPW feed lines connected to one of the radiating edges of the antennas.

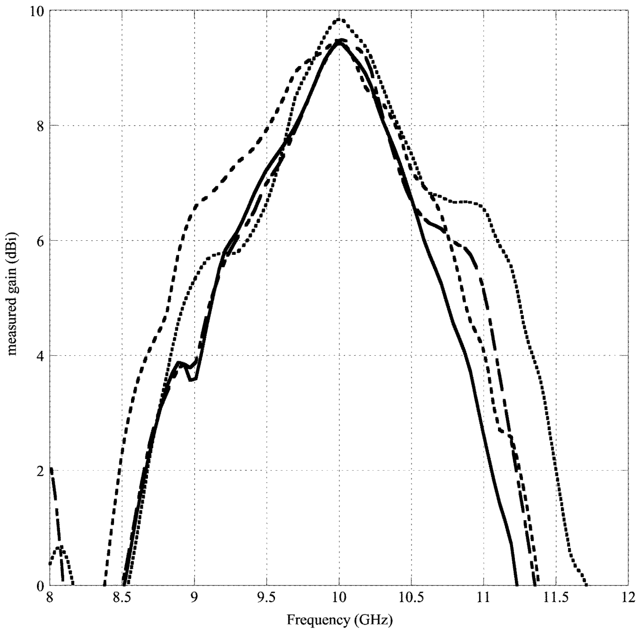
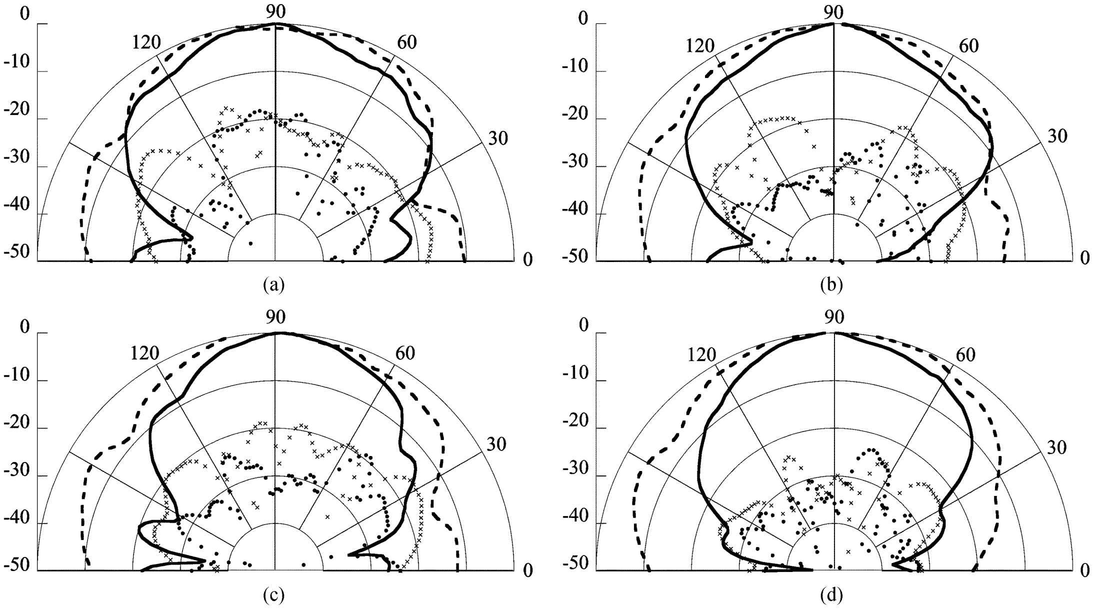


Fig. 3. Gain of the double-layered CPA. - - - - - - - - measured gain of AUT A, - - - - - - - measured gain of AUT B, ———— measured gain of AUT C, - - - - - - - measured gain of AUT D.

From Figs. 2–4, we can observe that different thickness combinations of the antennas change the characteristics of the antennas slightly, but it offers larger freedom in the input CBCPW feed line design and retains the uni-planar structure of the antenna surface, So it is an advantage especially for circuit integrations.

IV. CONCLUSION

This article has presented a simple design structure for broad-band coplanar patch antennas. The double-layered structure allows different layer thickness of the CBCPW feed line and the coplanar patch. An extra ground plane was inserted between the two dielectric layers, which controls the dimensions of the CBCPW without affecting the performance of the antennas seriously. The impedance bandwidth of the antenna is about 8.5%. The maximum gain of the antennas



(a) (b) (c) (d)

Fig. 4. Radiation patterns of the double-layered CPAs at 10 GHz (a) AUT A. (b) AUT B. (c) AUT C. (d) AUT D. ——— H-plane co-polarization, × × × × × H-plane cross-polarization, — — — — E-plane co-polarization, ● ● ● ● ● E-plane cross-polarization.

was 9.4 dBi within the pass band. The radiation patterns were stable and the maximum cross-polarization level of the antenna was about − 18 dB.

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Analysis of an Arbitrary Conic Section Profile Cylindrical Reflector Antenna, H-Polarization Case

Taner Oğuzer, Alexander I. Nosich, and Ayhan Altintas

***Abstract*—Two-dimensional scattering of waves by a perfectly electric conducting reflector having arbitrary smooth profile is studied in the H-polarization case. This is done by reducing the mixed-potential integral equation to the dual-series equations and carrying out analytical regularization. To simulate a realistic primary feed, directive incident field is taken as a complex source point beam. The proposed algorithm shows convergence and efficiency. The far field characteristics are presented for the reflectors shaped as quite large-size curved strips of elliptic, parabolic, and hyperbolic profiles.**

***Index Terms*—Analytical regularization, complex source, reflector antenna.**

I. INTRODUCTION

One of the most important segments of rapidly developing wireless communication systems is open-space propagation. In this research area the reflector antenna simulation, design and sophistication plays an important role because reflectors (Fig. 1) are one the best choices among the antennas with high directivity [1]. Besides, shaped radiation patterns are frequently needed or the beam can be focused on a near-zone target. In these configurations the reflectors may have elliptic, hyperbolic, parabolic or other specialized surfaces. Therefore it

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T. Oğuzer is with the Department of Electrical and Electronics Engineering, Dokuz Eylül University, Buca 35160, İzmir, Turkey (e-mail: taner.oguzer@kordon.deu.edu.tr).

A. I. Nosich is with the Institute of Radio-Physics and Electronics, National Academy of Sciences, Kharkov 61085, Ukraine.

A. Altintas is with the Department of Electrical and Electronics Engineering, Bilkent University, 06533 Ankara, Turkey.

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