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DESIGN AND APPLICATION OF A NOVEL CB-CPW STRUCTURE

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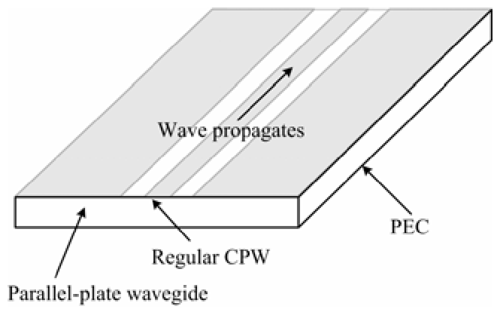
Abstract—On the base of conductor-backed coplanar waveguide (CB-CPW) structure, a novel CB-CPW structure is proposed and analyzed, which is realized by using the UC-PBG structure to replace the back conductor of CB-CPW. From 1.3 GHz to 2.8 GHz, The transmission characteristic of the proposed CB-CPW is better than that of CB-CPW, and is similar to that of CPW, therefore, this novel CB-CPW not only owns the advantage of CB-CPW, such as good mechanical strength and good heat yield, but also owns the advantage of CPW, such as good transmission characteristic. At last, a dual-band antenna based on this novel CB-CPW is designed and computed, the numerical results validate that this novel CB-CPW is feasible in microwave application.

1. INTRODUCTION

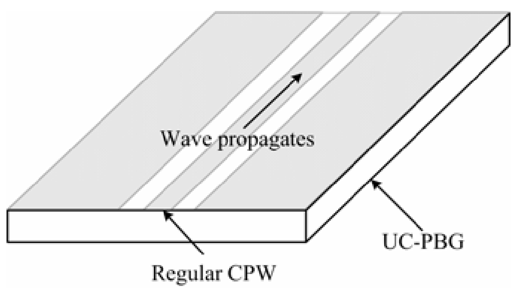
Coplanar waveguide (CPW) has been investigated comprehensively for applications both in microwave integrated circuits (MIC's) and monolithic-microwave integrated circuits (MMIC's) since its first introduction [1–6]. The conventional CPW is often backed with another ground plane to increase mechanical strength, realize mixed CPW microstrip circuits, or provide a heat sink [7]. The conductor-backed CPW (CB-CPW), however, will excited the parallel-plate mode and deteriorate CPW performance. Several approaches have been presented to overcome the leakage problem, such as using posts to short the unwanted mode or using multilayered substrates to shift the dispersion curve of the parallel-plate mode [8]. The proposed UC-PBG structure planes with a wide stopband can be easily etched in the back conductor of a CB-CPW circuits without using any extra masks or via holes and, therefore, is very promising for stopping the power leakage due to the paralle-plate mode [9–11].

2. DESIGN OF A NOVEL CB-CPW

Figure 1(a) shows the schematic of a conventional CB-CPW, where an additional ground plane is added to the back of a conventional CPW. A parallel-plate waveguide will be formed between top and bottom ground planes. The energy will leak along a particular angle once the wave is launched. This leakage is significant even at low frequencies, which will cause a sever effect, such as crosstalk, with neighboring circuits. The wide stopband of a UC-PBG structure can be used to suppress the propagation of this parallel-plate mode [12, 13].



(a) Conventional CB-CPW



(b) Proposed CB-CPW

Figure 1. The structure view of (a) a conventional CB-CPW and (b) a modified CB-CPW.

Figure 1(b) shows the schematic of a novel CB-CPW, which can effectively suppress the propagation of parallel-plate mode, and have little radiation loss. Meanwhile, compared with conventional CB-CPW, the additional ground plane is replaced by UC-PBG. This UC-

PBG structure also can work as heat sink and increase mechanical strength.

The FR4 substrate with $h = 1.6\,\text{mm}$ and $\varepsilon_r = 4.4$ is used for the simulated purpose. The top layer of the novel CB-CPW structure is conventional CPW structure. the width of the strip and slot of the CPW are chosen to be 3 mm and 0.3 mm, respectively, which give a characteristic impedance of $50\,\Omega$.

The bottom layer of the novel CB-CPW structure consists of UC-PBG structure shown in Fig. 2, which is proposed in literature [9, 10]. In this paper, by optimizing parameters, the stopband is realized from 1 GHz to 5 GHz. The metal pad and inductive branch have the following dimensions:

1) $a = 20\,\text{mm}$;
2) $s = g1 = 1\,\text{mm}$;
3) $g2 = 0.5\,\text{mm}$;
4) $h = 5\,\text{mm}$;

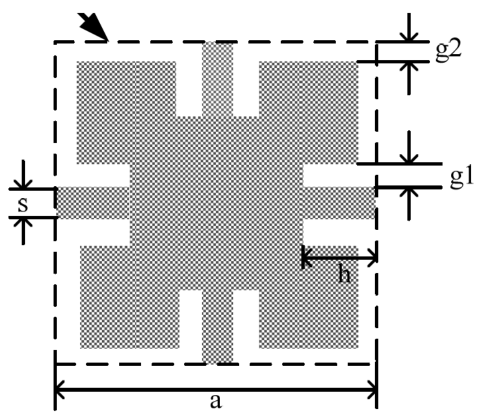


Figure 2. Schematics of one unit of the two-dimensional PBG lattice.

As shown by the dashed curve in Fig. 3, for the novel CB-CPW with a UC-PBG lattice, the insertion loss has been improved significantly from 1.3 GHz to 2.8 GHz, indicating that the parallel-plate mode has been suppressed almost completely at the frequency range that corresponds to the stopband of the UC-PBG structure. This novel CB-PCB structure shows great potential for applications in various types of CPW-based circuits, such as CPW-fed slot antennas.

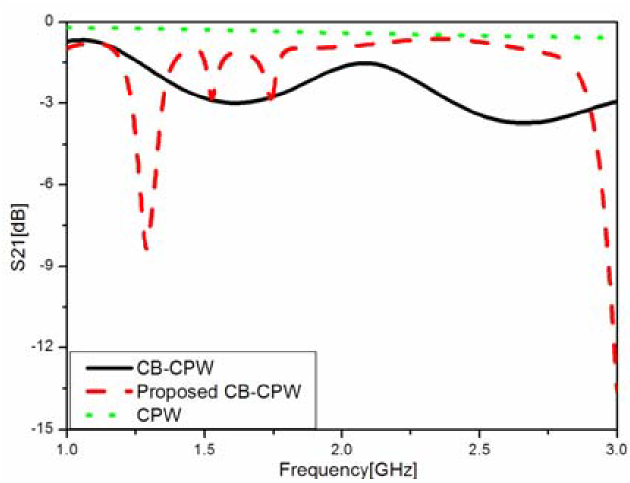


Figure 3. Simulated S_{21} of the proposed CB-CPW. The insertion losses of the conventional CPW and CB-CPW are also shown for comparison.

3. APPLICATION OF A NOVEL CB-CPW

Dual-band antennas are widely used in microwave communication. In this section, a dual-band antenna is designed by use of the proposed CB-CPW structure. This dual-band slot antenna is shown in Fig. 4, and the key geometry parameters of antenna are given in Table 1. and meanwhile, the commercial simulated software HFSS is used to compute the performance of dual-band antenna, which is programmed based on FEM (finite element method).

Table 1. Key geometry parameters of the dual-band slot antenna.

L×W(mm×mm)	$L_S \times W_S$(mm×mm)	S(mm)	d(mm)	t(mm)	b(mm)
44.9×19. 8	34.3×9. 2	1.9	3.4	12.9	3.5

In Fig. 5, the return loss of dual-band antenna based on the proposed CB-CPW is shown, the one of dual-band antenna based on

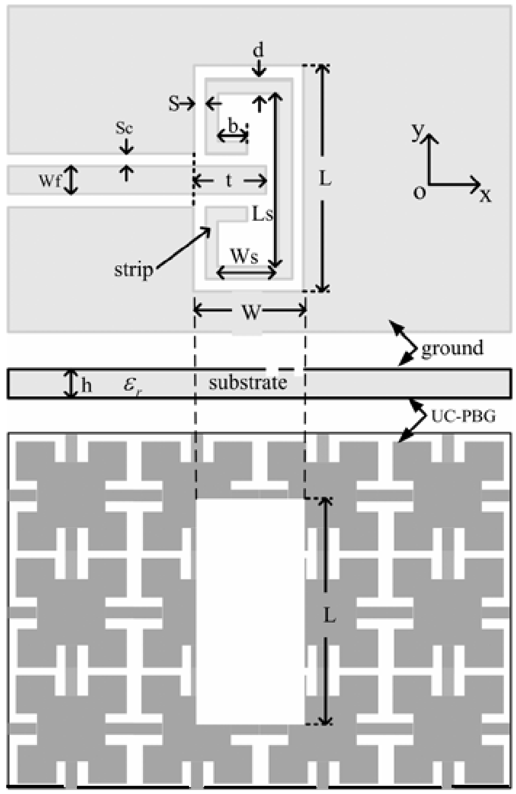


Figure 4. Geometry of dual-band antenna.

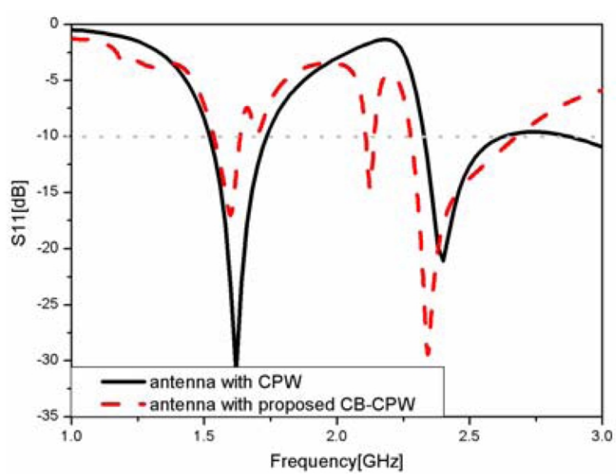
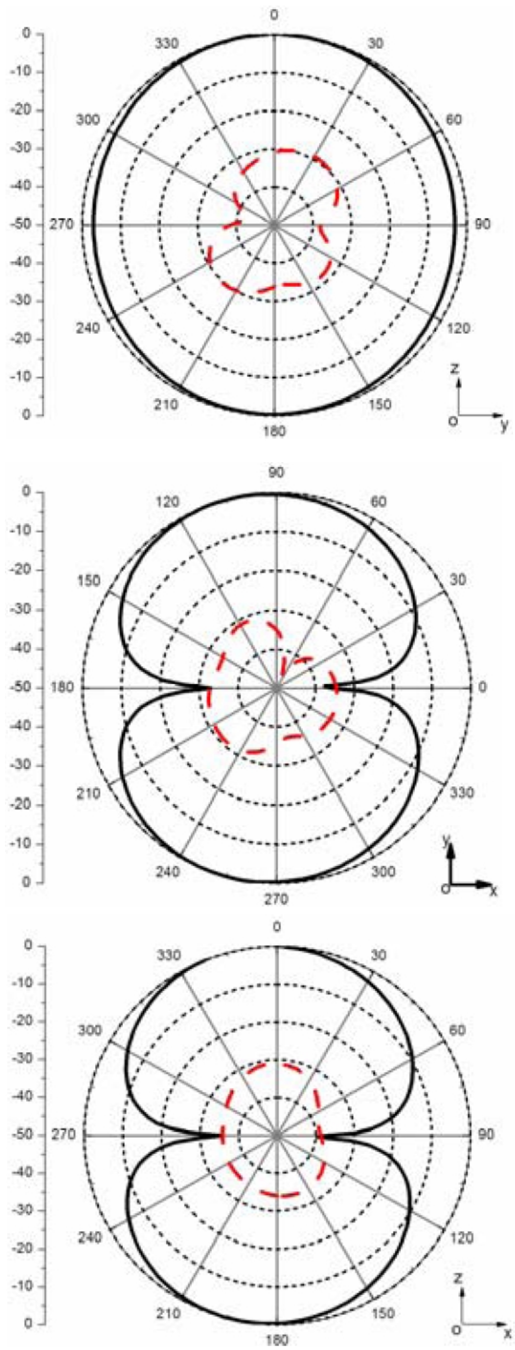


Figure 5. Return loss of dual-band antenna.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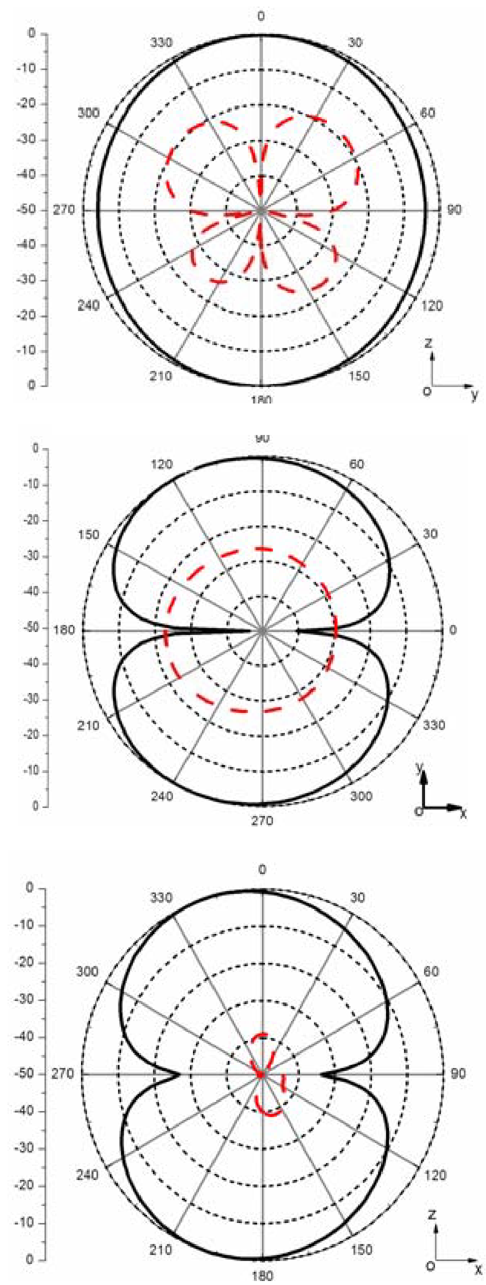
(a)



(b)

Figure 6. Radiation patterns of dual-band antenna with proposed CB-CPW at (a) 1.6 GHz and (b) 2.34 GHz.

the conventional CPW is also give for comparison.

The resonance frequencies of dual-band antenna based on the novel CB-CPW are 1.6 GHz and 2.34 GHz respectively. Due to the existence of UC-PBG lattices, at the high frequency end, the resonance frequency of antenna with novel CB-CPW is lower than that of antenna with conventional CPW, but the bandwidth with novel CB-CPW becomes wider. On the contrary, at the lower frequency end, there is little deviation between the resonance frequencies of two antennas.

At 2.13 GHz, the return loss of antenna with novel CB-CPW is also lower than −10 dB. according to the curve of antenna with conventional CPW, this frequency point is not excited by slots and is not demand. The reason maybe is that UC-PBG lattices works as a radiator coupling power from input end. In Fig. 5, it can be found that the simulated results are identical to the measured results except for 1.6 GHz.

Figure 6 illustrates the computed co- and cross-polarized far-field radiation patterns at 1.6 GHz and 2.34 GHz. From the results, it demonstrates that both the operating frequencies have the same polarization planes and similar radiation patterns and meanwhile, the radiation patterns is similar to that of dual-band slot antenna fed by the conventional CPW. It is also noted that cross-polarization levels at 1.6 GHz are less than −30 dB and at 2.34 GHz are less than −20 dB.

The simulated gains of the antennas with conventional CPW and with novel CB-CPW at the resonance frequencies are given in Table 2. It is demonstrated that the gain of antenna with proposed CB-CPW is slightly lower than that of antenna with conventional CPW owing to the existence of UC-PBG, but it is apparent that the gain of antenna with proposed CB-CPW is higher significantly than that of antenna with conventional CB-CPW due to the suppression of parallel-plane mode.

Table 2. Antenna gain at different frequencies.

f (GHz)	1.62	2.40	1.60	2.43
Gain of antenna with CPW (dB)	1.17	3.32		
Gain of antenna with proposed CB-CPW (dB)			0.37	2.23

4. CONCLUSION

This paper has proposed a novel CB-CPW structure. Its key feature is that UC-PBG is used to replace the additional ground plane of CB-CPW. By simulating this novel CB-CPW transmission line, it has good transmission characteristics of CPW at 1.3–2.8 GHz that is determined by UC-PBG and owns the merits of conventional CB-CPW, such as good mechanical strength and good heat yield. Finally, based on this novel CB-PBG, a dual-band slot antenna working at 1.6 GHz and 2.43 GHz is constructed. It has good radiation patterns, low cross-polarization level and high mechanical strength.

REFERENCES

1. Wen, C. P., "Coplanar waveguide, a surface strip transmission line suitable for nonreciprocal gyromagnetic device applications," *IEEE G-MTT Symp. Dig.*, 110–115, Dallas, TX, May 5–7, 1969.
2. Gupta, K. C., R. Garg, I. Bahl, and P. Bhartia, *Microstrip Lines and Slotlines*, Artech House, Norwood, MA, 1996.
3. Saed, M. A., "Broadband CPW-fed planar slot antennas with various tuning stubs," *Progress In Electromagnetics Research*, PIER 66, 199–212, 2006.
4. Liu, W. C., "Optimal design of dualband CPW-fed G-shaped monopole antenna for WLAN application," *Progress In Eelectromagnetics Research*, PIER 74, 21–38, 2007.
5. Qu, S. W., C. L. Ruan, and B. Z. Wang, "Bandwidth enhancement of a printed wide-slot antenna with a rotated slot," *IEEE Trans. Wirel. Propag. Lett.*, Vol. 5, 15–17, 2006.
6. Chen, Y. L., C. L. Ruan, and L. Peng, "A novel ultra-wideband bow-tie slot antenna in wireless communication systems," *Progress In Electromagnetics Research*, PIER 80, 101–108, 2008.
7. Shigesawa, H., M. Tsuji, and A. A. Oliner, "Conductor-backed slot line and coplanar waveguide: Dangers and full-wave analyzes," *IEEE MTT-S Int. Microwave Symp. Dig.*, 199–202, New York, May 25–27, 1988.
8. Liu, Y., K. Cha, and T. Itoh, "Nonleaky coplanar (NLC) waveguides with conductor backing," *IEEE Trans. Microwave Theory Tech.*, Vol. 43, 1067–1072, May 1995.
9. Yang, F. R., K. P. Ma, Y. X. Qian, and T. Itoh, "A uniplanar compact photonic-bandgap (UC-PBG) structure and its applications for microwave circuits," *IEEE Trans. Microwave Theory Tech.*, Vol. 47, 1509–1514, Aug. 1999.

10. Coccioli, R., F. R. Yang, K. P. Ma, and T. Itoh, "Aperture-coupled patch antenna on UC-PBG substrate," *IEEE Trans. Microwave Theory Tech.*, Vol. 47, 2123–2130, Nov. 1999.
11. Nedil, M., M. A. Habib, T. A. Denidni, and H. Boutayeb, "Quasi-metallic-wall technique for increasing the efficiency of CB-CPW antennas," *Progress In Electromagnetics Research*, PIER 78, 437–455, 2008.
12. Liu, W. N., J. K. Xiao, S. Zhang, and Y. Li, "A novel PBG planar inverted-F antenna for wearable system," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 5, 615–622, 2006.
13. Lindell, I. V. and A. H. Sihvola, "Perfect electromagnetic conductor," *Journal of Electromagnetic Waves and Applications*, Vol. 19, 861–869, 2005.