Slotted Conductor-Backed Coplanar Waveguide Antennas

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1. Introduction

Conductor-backed coplanar waveguide (CBCPWs) is a commonly used waveguide structure in planar printed circuits. It was found out that CBCPW always leaks power in a surface-wave form of the background parallel-plate mode [1]-[3], since the phase constant of the guided CBCPW mode is always less than that of the background parallel-plate mode. In waveguide applications, this surface-wave leakage will cause power loss and coupling between neighboring lines, and should be avoided in the operating frequency band using various mode-suppression schemes [4]-[5]. However, in antenna applications, we can place radiating slots on the top conductor or the bottom conductor [6] along the propagation direction of the parallel-plate surface-wave, resulting in a slotted antenna array structure similar to the slotted waveguide antennas in [7] or the radial line slot antenna in [8]. In this paper, we have designed a novel fan-shaped slotted CBCPW antenna operating in Ku band. Its center frequency is 12 GHz and can be used in direct broadcast satellite (DBS) systems.

2. Antenna Design

Fig. 1 illustrates the top view and the cross-sectional view of the antenna structure near the excitation port. For the CBCPW mode, the propagation constants, $k_y = \beta - j\alpha$, can be obtained by the spectral domain approach. They are shown in Fig. 2 with the designed parameters: the dielectric constant ε_r = 3.55, the substrate thickness h = 1.524 mm, the center feedline width S = 0.6 mm, and the gap width W=1mm. The propagation direction of the parallel-plate surface-wave mode, θ in Fig. 1, can be approximately obtained by $\theta = \cos^{-1}(\beta / k)$, where β is the phase constant of the CBCPW mode and k is the phase constant of the parallel-plate mode. Along the propagation direction of the parallel-plate mode, we place radiating slots that are tilted an angle ϕ from the propagation direction, as shown in Fig. 3. The power guided by the parallel mode can thus be radiated into the air through slots.

The tilt angle ϕ controls the amount of the radiation power. The normalized radiation resistances versus the tilt angle ϕ are shown in Fig 4, where the characteristic impedance Z_0 of the parallel-plate unit cell is 16.73 Ω. Following the design procedure in [8]-[9], we can design a slot array with appropriate tilted radiation slots to achieve a high-gain antenna.

3. Measurement Results

The antenna is designed on the Rogers 4003 substrate, with a dielectric constant ε_r = 3.55, a loss tangent tanδ = 0.0027, and the substrate thickness h = 1.524 mm. The CBCPW structure parameters are as follows: the center feedline width S = 0.6 mm, and the gap width W=1 mm, and the characteristic impedance of the CBCPW is 100 Ω. A section of tapered line is added to match the characteristic impedance of the 50 Ω SMA connectors. The geometrical parameters used for slots are: the slot width W_s = 0.5 mm, the slot length L_s = 8.6 mm, the distance between slots on the same radial line L_g =13.27 mm. We put 16 rows of slots on both sides of the top ground plates.and the tilt angle has a minimum value $\phi = 6.1°$ at the first row according to Fig. 4. The tilt angle ϕ is increasing from row to row. There are (17-*n*) slots on the *n*-th row. The total number of slots is 272 and the antenna size is 270.2 mm x 268.5 mm. Fig. 5 illustrates the top view of the whole antenna.

In Fig. 6, the measured return loss below -10dB is from 11.22 to 12.35 GHz. This antenna has a 9.4% bandwidth with a center frequency of 12 GHz. Fig. 7 shows the measured and simulated *yz*-plane copolarization radiation patterns at 12 GHz, with the measured antenna gain being 20.32 dBi and the sidelobe level below -15 dB. The simulation results are obtained by the software *Ansoft* HFSS.

4. Conclusion

This paper presents a novel CBCPW slot array antenna with a slot array. Using appropriate tilt angles, proper arrangement of slots and other optimized parameters, the antenna has a high gain and a low sidelobe level. It is noticed that CBCPW can be used as an excellent antenna structure with its power leakage of the no-cutoff parallel-plate mode.

Acknowledgments

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References

[1] H. Shigesawa, M. Tsuji, A. A. Oliner, "Conductor-backed slot line and coplanar waveguide: dangers and full-wave analyses," IEEE MTT-S International Microwave Symposium Digest, vol. 1, pp.199 – 202, May 25-27, 1988.

[2] R. W. Jackson, "Mode conversion at discontinuities in finite-width conductor-backed coplanar waveguide," IEEE Transactions on Microwave Theory and Techniques, vol. 37, No. 10, pp. 1582- 1589, Oct. 1989.

[3] W. E. McKinzie, N. G. Alexopoulos, "Leakage losses for the dominant mode of conductor-backed coplanar waveguide," IEEE Microwave and Guided Wave Letters, vol. 2, No. 2, pp. 65-66, Feb. 1992.

[4] Y. Liu, K. Cha, and T. Itoh, "Non-leaky coplanar (NLC) waveguides with conducting backing," IEEE Transaction on Microwave Theory Tech., vol. 43, no. 5, pp. 1067-1072, May 1995.

[5] F. R. Yang, K. P. Ma, Y. Qian, and T. Itoh, "A uniplanar compact photonic-bandgap (UC-PBG) structure and its applications for microwave circuits," IEEE Transaction on Microwave Theory Tech., vol. 47, no. 8, pp. 1509-1514, Aug. 1999.

[6] I.-C. Lan, P. Hsu, "Parallel-plate slot array fed by conductor-backed coplanar waveguide," European Microwave Conference, Paris, Vol. 1, Oct. 2005.

[7] R. S. Elliott, *Antenna theory and design*, 2nd ed., John Wiley & Sons, Inc., 2003.

[8] M. Ando, T. Numata, J.-I Takada, N. Goto, "A linearly polarized radial line slot antenna", IEEE Transactions on Antennas and Propagation, vol. 36, issue 12, pp. 1675-1680, Dec. 1988.

[9] J. Gulick, G. Stern, R. S. Elliot, "The equivalent circuit of a rectangular-waveguide-fed longitudinal slot," Antennas and Propagation Society International Symposium 1986, vol. 24, pp. 685-668, Jun 1986.

[10] R. Shavit, "Impedance characteristics of a slot antenna fed by a parallel plate waveguide," Microwave and Optical Technology Letters, vol. 14, No. 2, pp.126-128, February 1997.

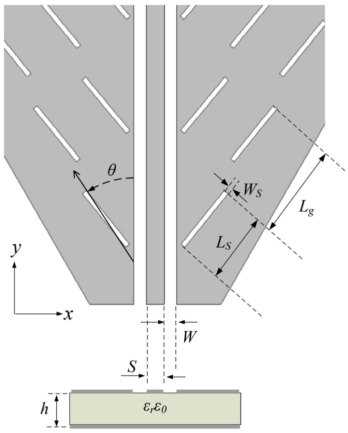

Figure 1: The top view and the cross-sectional view of the antenna

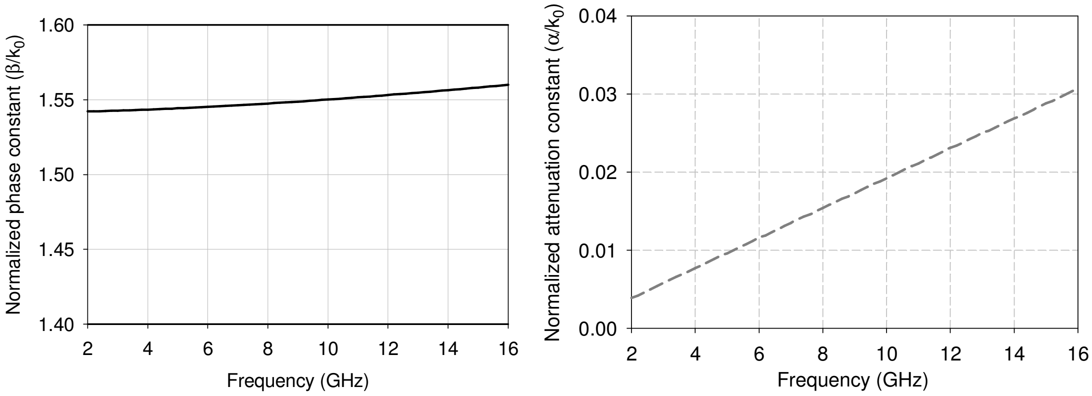

Figure 2: The normalized propagation constants of the CBCPW mode

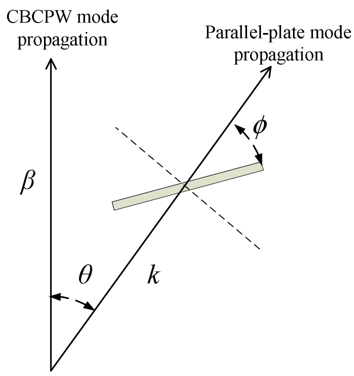

Figure 3: The propagation directions of CBCPW mode and parallel-plate mode

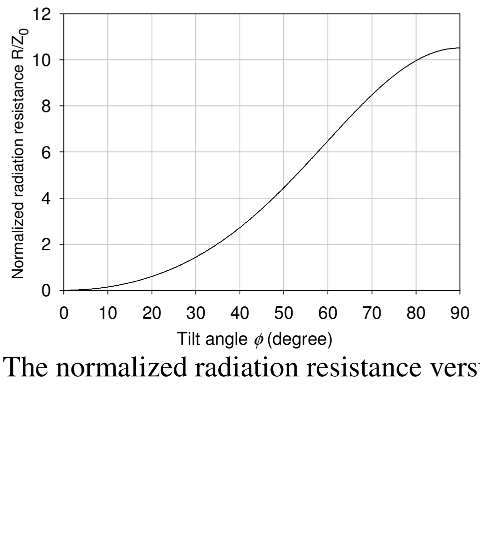

Figure. 4 The normalized radiation resistance versus tilt angle

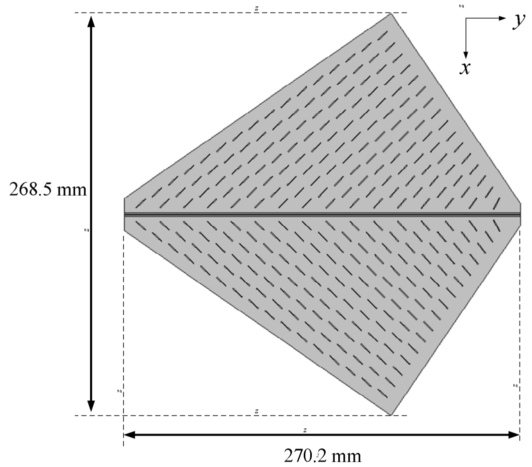

Figure 5: The slotted conductor-backed coplanar waveguide antenna

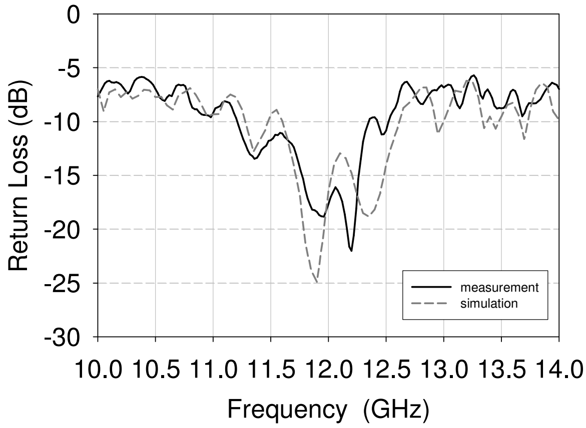

Figure 6: Measured and simulation return losses

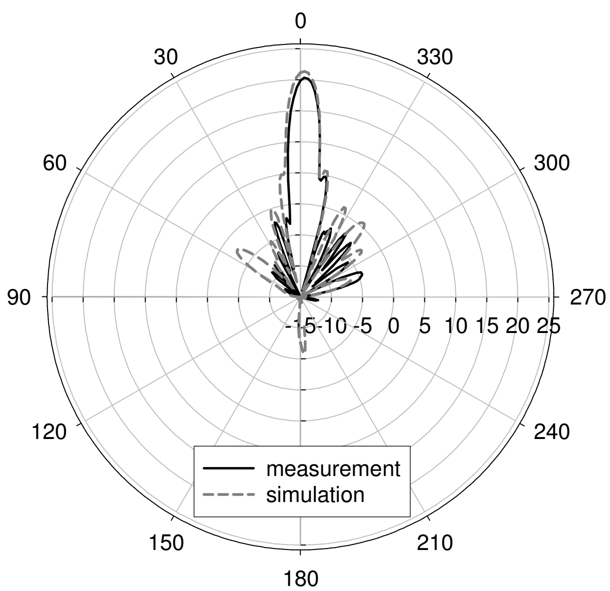

Figure 7: Measured and simulated radiation patterns at 12 GHz