Effects of Air-Gap on Leakage-Loss of Conductor-Backed Coplanar Waveguide with Air-Gap-Spacing Dielectric Sheets

Masashi HOTTA, Ai KARITA, Shiro NAKAYAMA, Atsushi KOHNO, AND Mitsuo HANO

Department of Electrical & Electronic Engineering, Yamaguchi University
2-16-1 Tokiwadai, Ube, Yamaguchi 755-8611, JAPAN
Tel.: +81-836-85-9436, Fax.: +81-836-85-9401
E-mail: hotta@po.cc.yamaguchi-u.ac.jp

Low leakage-loss of Conductor-Backed Coplanar Waveguide (CBCPW) with air-gap-spacing (AGS) dielectric sheets has been already proposed numerically by using the hybrid 2D-FDTD analysis and the curve-fitting procedure. From the numerical results, the low leakage-loss characteristics and the existence of the optimum width for the air-gap have been confirmed. In this paper, we have mainly discussed on the relationship between the leakage-loss and the location of the air-gap. To explain this relationship, we have analyzed the characteristics for asymmetrically located air-gap structure. As the first step, the air-gap width is expanding toward the right-way with keeping the position of another side edge, as the next step, the location of the air-gap is moved toward the right-way with keeping the air-gap width. From these analytical results, we have also tried to find out what is dominantly affected on the leakage-loss reduction of CBCPW with AGS dielectric sheets.

1 Introduction

To realize the high performance Microwave Integrated Circuits (MIC's) and Monolithic Microwave Integrated Circuits (MMIC's), the easy handling and low-loss transmission line is required. The planar type microwave circuits are much easy to integrate by using multilayered techniques, and so on. The coplanar waveguide (CPW), that is the typical planar type microwave and millimetre-wave transmission line, is a fundamental and important element due to its compatibility with the flip-chip technology and ease for mounting of active devices. The original structure of CPW has a substrate without any metallization on the backside, however, in the case of the most practical applications, its substrate is backed with conducting material [1], [2]. The conductor-backed CPW (CBCPW) loses its modal power into leaky waves and it has been pointed out that the leaky waves have harmful influence on the other peripheral elements [2]. To reduce the leakage-loss, the CBCPW with the grooving substrate have been proposed [3], [4], but it is much expensive to process the shape modification of substrate in the practical manufacturing. So, by no modification of the substrate shape, we have proposed the low leakage-loss CBCPW structure with air-gap-spacing (AGS) dielectric sheets [5], [6].

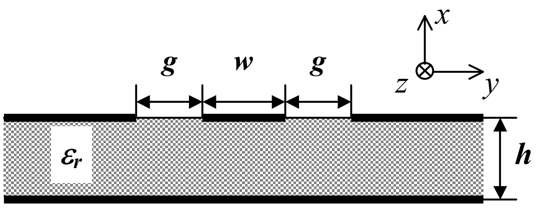
In this paper, it is clarified that the appropriately arranged dielectric sheets on the backside of CBCPW substrate across an air-gap play the same role of grooving structure and can be sufficiently reduced the leakage-loss of CBCPW. Furthermore, by investigating the relation between the position of the air-gap size and the leakage-loss of CBCPW more in detail, we discuss what is dominantly affected on the leakage-loss reduction of CBCPW with AGS dielectric sheets. Finally, we have discussed what is dominantly affected on the leakage-loss reduction of CBCPW with AGS dielectric sheets.

2 Low Leakage-Loss CBCPW with AGS Dielectric Sheets

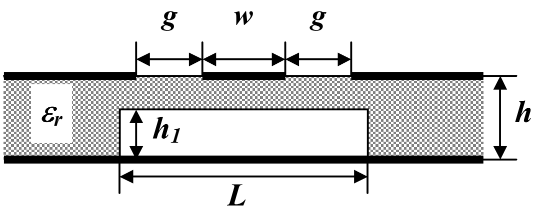
The structure of the conventional CBCPW investigated in this paper is shown in **Fig. 1(a)**, together with the coordinate system. It is assumed that the CBCPW has an infinite extension toward the $\pm y$ direction. The substrate used in this study is GaAs with $\varepsilon_r = 12.9$ and $h = 100\ \mu$m. The other structural parameters are: $w = 120\ \mu$m and $g = 96\ \mu$m [3]. Perfect conductor with negligible thickness has been assumed here, since it is well-known that the propagation loss in the CBCPW is dominated by leakage-loss into the parallel-plate mode.

Here, the low leakage-loss CBCPW structure with a groove on the backside [3], [4], and with AGS dielectric sheets [5], [6] which have been proposed by one of the authors are also shown in **Figs.1(b)** and **(c)**, respectively. In this proposed structure, the groove or air-gap is on the backside centre of the substrate.

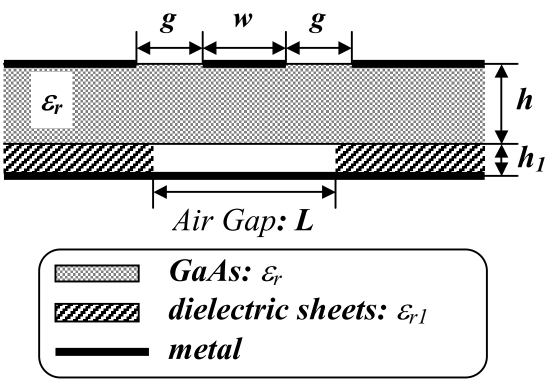
Figs.2(a) and **(b)** show the leakage-loss characteristics for conventional CBCPW [7] and the CBCPWs with low permittivity AGS dielectric sheets where the range of air-gap width, *L*, is 120 to 888mm in **Fig.2(a)** and 312 to 888mm in **Fig.2(b)**, respectively. After now, in the numerical simulation, we have assumed that the thickness and the dielectric constant of



(a) Conventional CBCPW

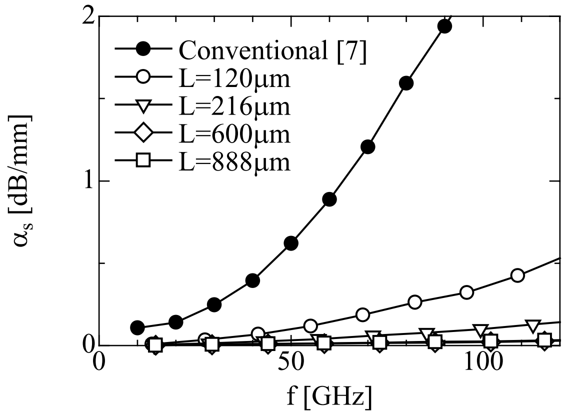


(b) Grooving CBCPW

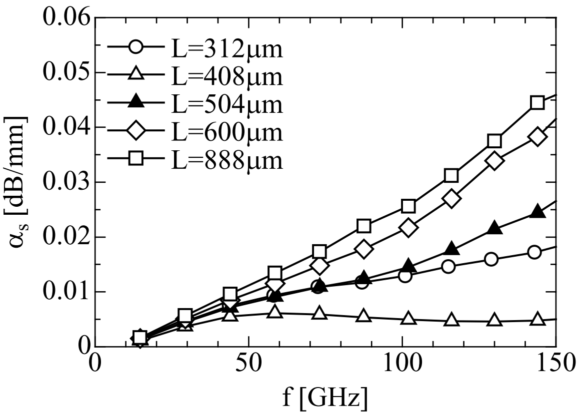


(c) CBCPW with AGS dielectric sheets.

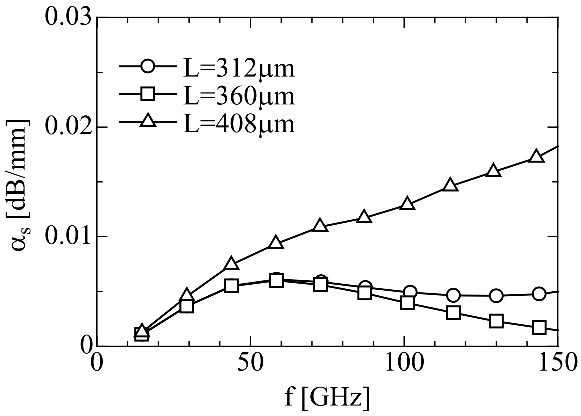
Fig. 1 Geometry of CBCPW



(a) Conventional and typical AGS dielectric sheet inserted CBCPW.



(b) AGS dielectric sheet inserted CBCPW.



(c) Detailed analysis.

Fig.2 Leakage-Loss characteristics for CBCPW with symmetrically located AGS dielectric sheets, where h_1 = 40μm and ε_{r1} = 5.0, respectively.

inserted dielectric sheets are set as h_1 = 40μm and ε_{r1} = 5.0, respectively. From these results, it is presented that the leakage-loss of the CBCPW with AGS dielectric sheets drops radically over the wide rage of frequency. This result indicates that by inserting the AGS dielectric sheets, we can design low-loss CBCPW structures without modifying the substrate shape to improve the performance of MIC's and MMIC's. Furthermore, at the air-gap width L = 408μm, the remarkable leakage-loss reduction can be observed over wide frequency range. To conjecture the optimum structure of CBCPW with AGS dielectric sheet, more in detail, we estimate the leakage-loss characteristics around L = 408μm again. The results are shown in **Fig.2(c)**. From this result, it is indicated that the optimum air-gap width under this structural parameter is just around L=360μm.

3 Effects of Air-Gap Location

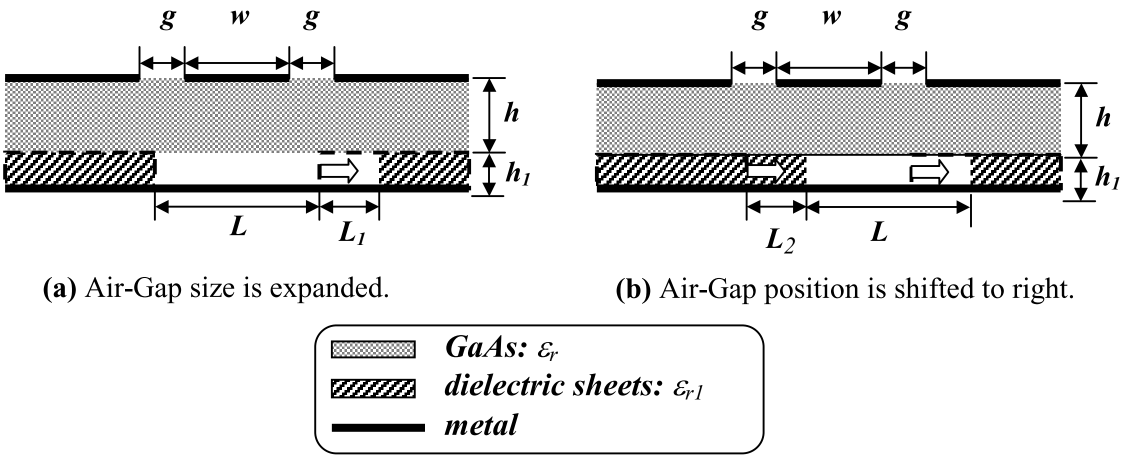
To make clear the effects of the air-gap location on the leakage-loss reduction, we have estimated the leakage-loss characteristics for the CBCPW with AGS dielectric sheets by changing the size or position of the air-gap. The parameters of the dielectric sheet are h_1 = 40μm and ε_{r1} = 5.0. The other CPW structural parameters are the same as those in **Fig.2**. As the first step, we consider that the air-gap width is expanded to L+L_1 toward the right with keeping the one-end at the same position as shown in **Fig.3(a)**. For the second step, the location of the air-gap is horizontally shifted L_2 from the centre to right with keeping the air-gap width L as shown in **Fig.3(b)**. In the both case, the other fundamental CPW parameters are the same as **Fig.1(c)**.

Fig.4(a) shows the leakage-loss characteristics for CBCPW with AGS dielectric sheets in the case of the air-gap size is expanded L_1=-48, +48, and +96μm. Here, the left-side end of the air-gap has been kept at the same position and initial air-gap width L is set as 360μm which is the optimum width of CBCPW with symmetrically located AGS dielectric sheets as presented in **Fig.2**. Here, the minus value of L_1 indicates that the air-gap width is shrinking case. From this result, the leakage-loss becomes large as the absolute value of the asymmetrically expanded width L_1 becomes wider.

Fig.4(b) presents the leakage-loss characteristics for CBCPW with AGS dielectric sheets whose air-gap position is shifted away from the centre of CPW, but the air-gap width is kept at L = 456μm that is 96μm wider than the optimum width. The shifted distance L_2 is set as 0, 48, 96 and 120μm, respectively. From this result, the leakage-loss becomes low over L_2 is 0 to 48μm. Please notify that, in the case of L_2= 48μm, the position of the left-side edge of the air-gap is just agree with the position at that the optimum width of the centred air-gap (L = 360μm) structure. From these results, it seemed to be predicted that the effects of the dielectric edge or corners of the air-gap is much contributed on the leakage-loss reduction of CBCPW with AGS dielectric sheets.

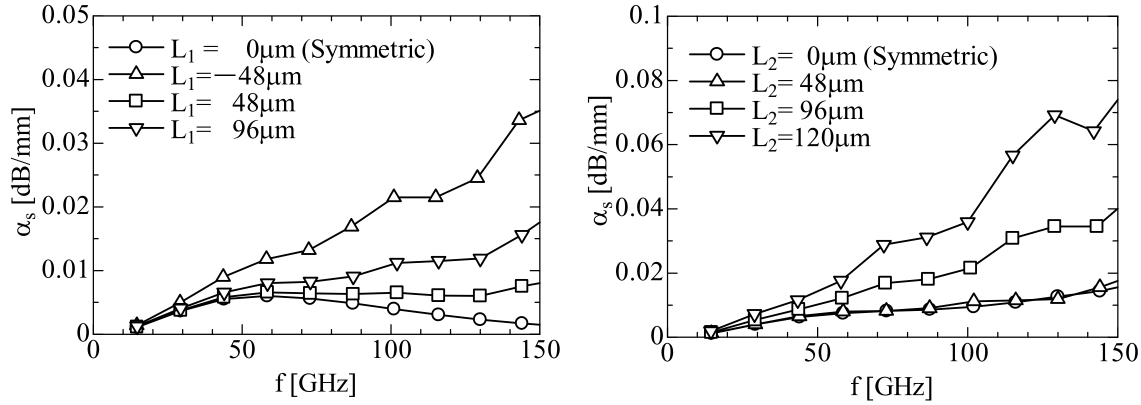
4 Conclusions

The leakage-loss characteristics of CBCPW with the symmetrically and the asymmetrically



(a) Air-Gap size is expanded. **(b)** Air-Gap position is shifted to right.

Fig.3 Air-Gap location of CBCPW with AGS dielectric sheets for the analysis.



(a) The size of the air-gap [a*symmetric*] ($L = 360\mu$m)

(b) The position of the air-gap. ($L = 456\mu$m)

Fig.4 Leakage-loss characteristics for CBCPW with AGS dielectric sheets by changing the size or position of the air-gap, where $\varepsilon_{r1} = 5.0$, $h_1 = 40\mu$m, and the other parameters are the same as those in **Fig.2**.

located AGS dielectric sheets are analysed in this paper. The numerical results show that the leakage-loss of CBCPW can be much reduced by inserting the low permittivity dielectric sheets and constructing the air-gap. It is also seemed to be existed the optimum air-gap width. Furthermore, when the position of the one-side edge of the asymmetrically located AGS dielectric sheets is coincided with that of the optimum air-gap width of the symmetrically located AGS dielectric sheets, the leakage-loss becomes small. From these results, it is confirmed that the effects of the dielectric edge or corners of the structure is much contributed on the leakage-loss reduction of CBCPW with AGS dielectric sheets.

Acknowledgement

The one of the authors would like to thank Professor Tatsuo Itoh of the Electrical Engineering Department, University of California, Los Angeles and Dr. Yongxi Qian of the Microsemi Co., for their variable and important discussions and comments on the first-step of this study.

References

[1] K. C. Gupta , R. Garg, I. Bahl, and P. Bhartia, *Microstrip lines and slotlines*, *2nd Ed.*, Artech House, Boston, 1996, Chap.7.

[2] H. Shigesawa, M. Tsuji, and A.A.Oliner, "Conductor-Backed Slot Line and Coplanar Waveguide: Dangers and full-wave analyzes," 1988 IEEE MTT-S Int. Microwave Symp. Dig., pp.199-202.

[3] M. Hotta, Y. Qian, and T. Itoh, "Leakage Loss Analysis of Conductor Backed Coplanar Waveguide with a Hybrid 2D-FDTD/Marquardt Technique,'' Proc. 1998 Asia-Pacific Microwave Conf., vol.2, pp.409-512.

[4] M. Hotta, Y. Qian, and T. Itoh, "Efficient FDTD Analysis of Conductor Backed CPW's with Reduced Leakage Loss,'' IEEE Trans. Microwave Theory & Tech., vol.47, no.8, pp.1585-1587, Aug. 1999.

[5] M. Hotta, K. Kisaka, T. Inoue, and M. Hano, "Leakage Loss Reduction of Conductor Backed Coplanar Waveguide Backed with Dielectric Sheets," Proc. 2000 Japan-China Joint Meeting on Optical Fiber Science and Electromagnetic Theory (Osaka, Japan), pp.365-368,Dec. 2000.

[6] M. Hotta, T. Inoue, M. Kobayashi, and M. Hano, "Leakage Loss Analysis of Conductor Backed Coplanar Waveguide with Air-Gap-Spacing Dielectric Sheets," Trans. IEICE on Electron., vol.E85-C, no.7, pp.1519-1522, July 2002.

[7] T. Krems, W. H. Haydl, M. Massler, and J. Rudiger, "Advantages of flip chip technology in millimeter-wave packaging," 1997 IEEE MTT-S Int. Microwave Symp. Dig., pp.987-990.