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BENDS IN NONRADIATIVE DIELECTRIC WAVEGUIDES

Tsukasa Yoneyama, Shigeo Nishida and Masayuki Yamaguchi
Research Institute of Electrical Communication
Tohoku University
Katahira 2-chome, 1-1, Sendai, Japn 980

An experimental study was made of bends in the nonradiative dielectric waveguide at 50 GHz. The main cause of the bending loss was found to be the reflection at the transitions between the straight and curved waveguides rather than the radiation. A bend with a curvature radius as small as one guide wavelength could be realized.

Introduction

Although transmission losses of dielectric waveguides are reasonably small along the straight sections, radiation losses at the bends are often formidable. Reducing the radiation losses is an urgent need when using dielectric waveguides in millimeter-wave integrated circuits. Use of the trapped image guide[1] is one possible candidate for this purpose and the nonradiative dielectric waveguide(NRD-guide)[2,3] is another which has been proposed as a radiation free dielectric waveguide.

The NRD-guide substantially resembles the H-guide[4] in structure, except that the sidewall separation is smaller than half a wavelength. Since the electric field is parallel to the metal plates, radiation, if any, is suppressed due to the cutoff property of the sidewalls. However, the cutoff is eliminated along the dielectric strips and waves are able to propagate freely, whether the strips be straight or curved. In order to confirm applicability of the NRD-guide in millimeter-wave integrated circuits, an experimental study was made of 90° and 180° bends at 50 GHz.

Measurements showed that the NRD-guide can almost completely suppress the radiation at the bends as expected, so that a minimum radius of bending is determined by the reflection rather than the radiation. The width of the dielectric strip was experimentally optimized in order to reduce the reflection at the bend, and a bend with a curvature radius as small as one guide wavelength could be realized.

Measurements

Fig.1 is a sketch of a 90° bend. Polystyrene(ε_r = 2.56) was chosen as strip material because of its good machinability, and brass plates were used as the sidewalls. The dielectric strip was 2.7 mm in height and 2.4 mm in width, and the sidewall separation was 2.7 mm so as to hold the strip tightly. The radius of bending was varied as R = 20 mm, 16 mm, 12 mm, 10 mm and 8 mm, and the width of the dielectric strip(b_c) at the curved section was made equal to or smaller than the normal width 2.4 mm depending on the value of R by the reason explained later. Tapers about 15 mm in length, when necessary, were provided to realize smooth transitions between the straight guides and the bends of the reduced width. The bending losses were measured by the substitution method using a straight strip equal in length to the bend as the standard of comparison to remove the effect of the transmission loss. Since a 50 GHz sweeper was not available, a klystron oscillator was used in a manual tuning operation. This handicap somewhat deteriorated the accuracy of the measurements.

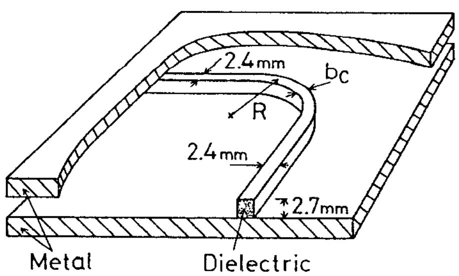

Fig.1 Sketch of 90° bend in NRD-guide

Fig.2 shows the results of the loss measurements for the case of R = 20 mm. The bending losses are negligible. This is surprising considering the large amount of radiation loss which might be caused at the bend of such a small curvature radius in an ordinary image guide[5]. This fact emphasizes the advantage of using the NRD-guide in millimeter-wave integrated circuits.

The bending losses for the case of R = 16 mm are shown in Fig.3(a). Several peaks appeared in the loss curve. These peaks can be attributed to the reflection rather than the radiation. Among several methods tried for the purpose of eliminating the reflection, narrowing the strip at the curved section was found to be the most effective. In fact, the peaks disappeared as shown in Fig.3(b) with a reduction in the width of the strip by 0.2 mm along the curved section(b_c = 2.2 mm). This is in contrast to the case of the image guide, in which the bending losses increase due to the increase of the radiation, if the strip is narrowed at the bend. A theoretical explanation for this reduction of the reflection is possible if the shift of the field maximum at the curved section is taken into account[6]. The narrower the strip, the less the shift of the field maximum and hence the less the reflection. In this respect, a theory is being developed to better understand the performance of the bend of a very small curvature radius.

Further results for smaller values of R with the reduced widths of the strips are presented in Fig.4. The bending losses are almost eliminated in Figs.4(a) and (b), but in the case of R = 8 mm in Fig.4(c), the reflection still remains even if the strip is narrowed to 1.8 mm. Further reduction of the strip width might eliminate the remaining reflection, but it is not practical since the operational bandwidth of the bend decreases as the strip narrows. Taking this into consideration, it may be said that a practical minimum radius of bending is somewhat larger than 8 mm or, in other words, it is about one guide wavelength, that is, 8.7 mm in this case.

Very similar results were obtained for 180° bends. As an example, the case of R = 12 mm is shown in Fig.5. Comparing Figs.5(a) and (b) shows that narrowing the strip is still effective for reducing the bending losses of the 180° bends.

Conclusions

Measurements were made of the NRD-guide bends. The bending loss was found to be negligibly small. Though the transmission loss of the NRD-guide increases slightly due to the small sidewall separation, the reduction in the bending loss sufficiently covers this disadvantage. Since very sharp bends can be easily made, the NRD-guide is believed to be useful for realizing complicated dielectric waveguide components for millimeter-wave integrated circuit applications.

A theory is being developed in order to better understand the performance of the NRD-guide bend, and some interesting results are being obtained.

References

1. T. Itoh and B. Adelseck, "Trapped image guide for millimeter-wave circuits," IEEE Trans. Microwave Theory and Tech., Vol.MTT-28, pp.1433-1436, Dec. 1980.
2. T. Yoneyama and S. Nishida, "Nonradiative dielectric waveguide for millimeter-wave integrated circuits," IEEE Trans. Microwave Theory and Tech., Vol.MTT-29, pp.1188-1192, Nov. 1981.
3. T. Yoneyama and S. Nishida, "Nonradiative dielectric waveguide circuit components," Digest of 6th Int. Conf. on Infrared and Millimeter-Waves, W-3, Dec. 1981(Miami).
4. F. J. Tischer, "A waveguide structure with low losses," Arch. Elec. Ubertragung, Vol.7, pp.592-596, Dec. 1953.
5. K. Solbach, "The measurement of the radiation losses in dielectric image line bends and the calculation of a minimum acceptable curvature radius," IEEE Trans. Microwave Theory and Tech., Vol.MTT-27, pp.51-53, Jan. 1979.
6. T. Trinh and R. Mittra, "Field profile in a single-mode curved dielectric waveguide of rectangular cross section," IEEE Trans. Microwave Theory and Tech., Vol.MTT-29, pp.1315-1318, Dec. 1981.

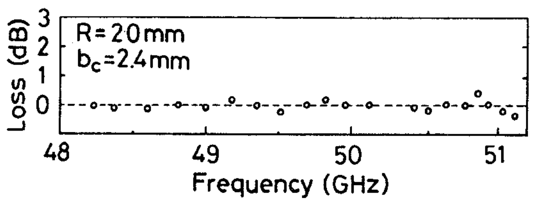

Fig.2 Bending losses of a 90° bend(R = 20 mm) without reduction in strip width

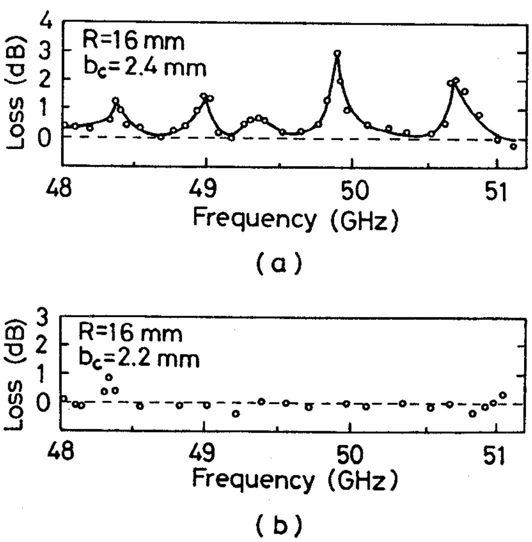

Fig.3 Comparison of bending losses of 90° bends(R = 16 mm) with (a) b_c = 2.4 mm and (b) b_c = 2.2 mm

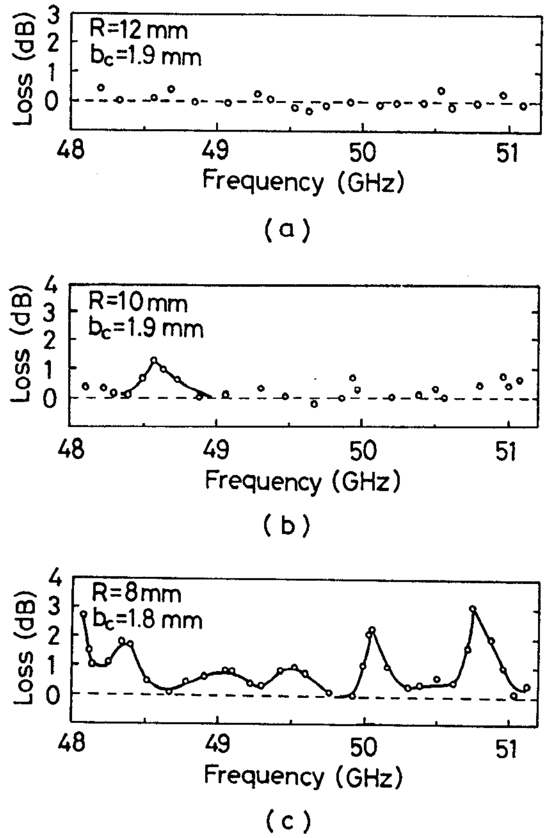

Fig.4 Comparison of bending losses of 90° bends

(a) R = 12 mm and b_c = 1.9 mm

(b) R = 10 mm and b_c = 1.9 mm

(c) R = 8 mm and b_c = 1.8 mm

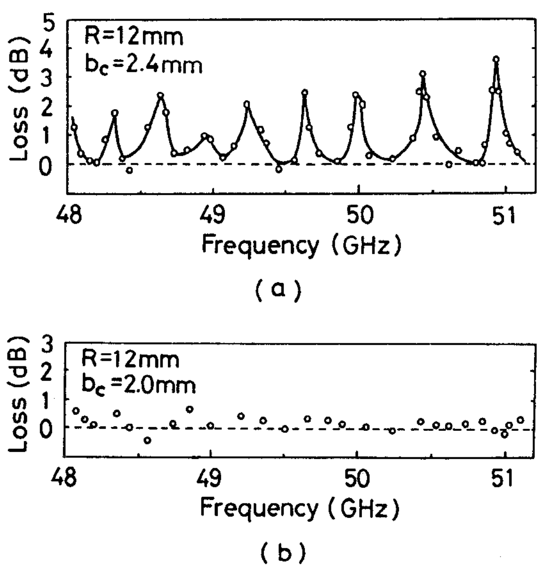

Fig.5 Comparison of bending losses of 180° bends(R = 12 mm) with (a) b_c = 2.4 mm and (b) b_c = 2.0 mm