Loss Reduction of Microstrip-to-Waveguide Transition Suppressing Leakage from Gap between Substrate and Waveguide by Choke Structure

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***Abstract* – A microstrip-to-waveguide transition can be used for connecting antennas and backed RF circuits. Loss of the transition due to the leakage from the gap between the substrate and the waveguide has been a serious problem in the millimeter-wave band. A choke structure is provided in the gap at the quarter wavelength away from the waveguide edge to suppress the leakage. The effect to use the choke structure is demonstrated by simulation in this paper.**

***Index Terms* — Milimeter wave, Transmission-line transition, Microstrip line, Waveguide, Choke structure.**

1. Introduction

Millimeter-wave technologies have been developed for automotive radars [1], [2] and high-bit-rate wireless communication systems [3]. Microstrip-to-waveguide transitions have been used for low-loss connections between the microstrip antennas and backed RF circuits through the waveguide [4], [5]. The microstrip-to-waveguide transitions were assembled by a substrate setting on a metal plate with a waveguide. However, the loss due to the leakage from the gap between the substrate and the waveguide is a serious problem in the millimeter-wave band. Then, we propose a choke structure provided in the gap at the quarter wavelength away from the waveguide edge to suppress the leakage. The geometrical parameters of the choke structure on the metal plate with the waveguide are optimized by using an electromagnetic simulation of the finite element method in the millimeter-wave band.

2. Structure and Principle of Choke Structure

The structure of the planar microstrip-to-waveguide transition is shown in Fig. 1. A microstrip line and a short plate are placed on the upper plane of the dielectric substrate and a matching patch and ground plate are placed on the lower plane. Once the signal inputs from the microstrip line, the electromagnetic field at the end of the signal line of the coplanar structure is electromagnetically coupled to the matching patch. Finally, the RF power radiates from the patch into the waveguide. The microstrip-to-waveguide transition is assembled by a substrate with metal pattern setting on the metal plate with a waveguide. When there is a gap between the substrate and the metal with the waveguide as shown in Fig. 2, parallel plate mode can propagate in the gap, which causes loss of the transition. Then, we propose to form a choke structure. A groove surrounds a waveguide whose open circuit is located at a quarter wavelength away from the waveguide edge which performs an equivalent short circuit. The dielectric material of the substrate is fluorocarbon resin film (thickness t = 0.127 mm, ε_r = 2.2). Waveguide is WR-12 (3.1 x 1.55 mm). The gap g between the substrate and the metal with the waveguide is set to be 0.1 mm in simulation for confirmation of choke effect.

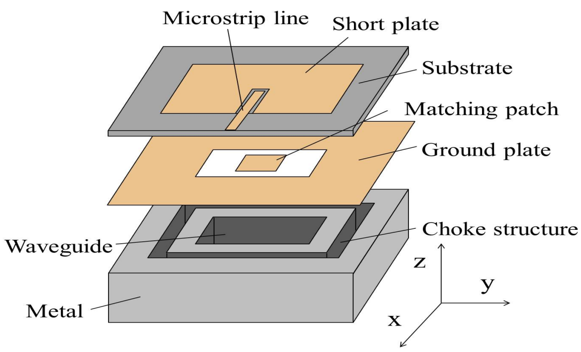


Fig. 1. Structure of the microstrip-to-waveguide transition with the choke structure.

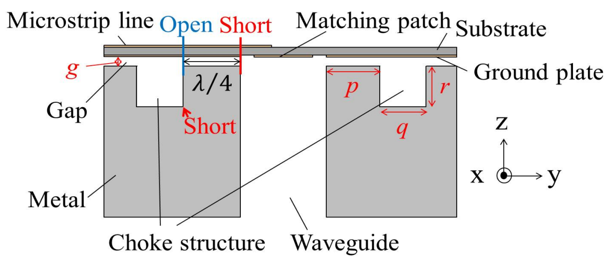


Fig. 2. Principle of the choke structure in the cross-sectional view of the microstrip-to-waveguide transiton.

3. Analysis Results

The optimized parameters of the choke structure are listed in Table I. The reflection and transmission characteristics obtained by changing the choke depth r are shown in Figs. 3 and 4. The resonant frequencies of reflection characteristics

S_{11} were almost stable within 0.5 GHz from the design frequency 79 GHz by changing *r*. The transmission S_{21} was maximum when *r* was 1.0 mm.

The frequency characteristics of the transition with the optimized choke are shown in Fig. 5. At the design frequency 79 GHz, the reflection and transmission characteristics were improved by the choke structure and they approached to the frequency characteristics without gap. The comparison of the electric field distributions in the gap is shown in Fig. 6. The loss due to the leakage from the gap was generated without the choke structure as shown in Fig. 6 (a), while the loss was suppressed with the choke structure by formed a standing wave as shown in Fig. 6 (b).

The effect of the choke is evaluated for the gap from 0.1 mm to 0.5 mm by simulation. As shown in Fig. 7, when *g* was 0.5 mm, the loss without the choke structure was 2.9 dB, while the loss with the choke structure was reduced to be 1.0 dB. The loss in 79 GHz band was suppressed by the effect of the optimized choke structure for *g* over 0.1 mm to 0.5 mm.

TABLE I
Parameters of the Choke Structure

Parameters	Value[mm]
Gap *g*	0.1
Position *p*	1.25
Width *q*	1.0
Depth *r*	1.0

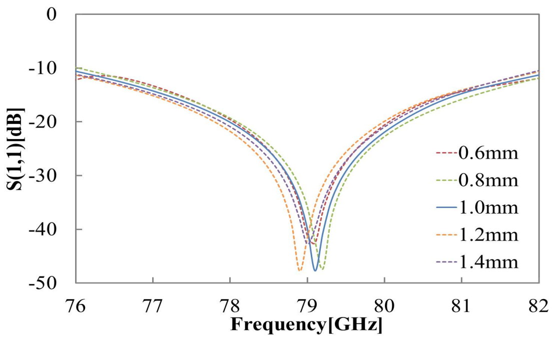


Fig. 3. Reflection characteristics depending on the depth *r*.

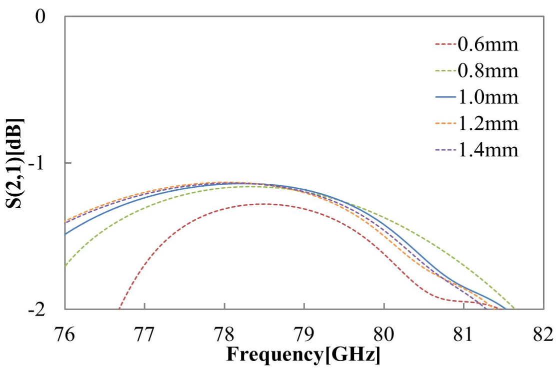


Fig. 4. Transmission characteristics depending on the depth *r*.

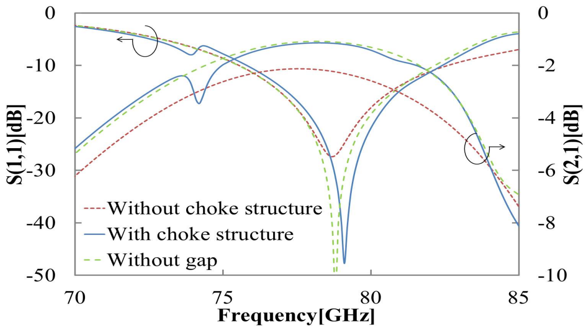
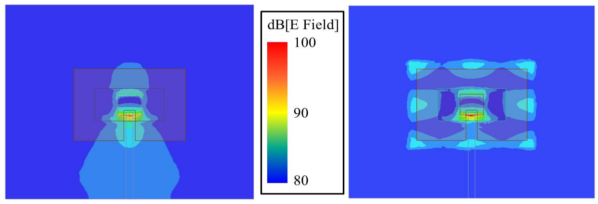


Fig. 5. Comparison of the frequency characteristics.



(a) Without choke structure (b) With choke structure
Fig. 6. Comparison of the electric field distributions in the gap.

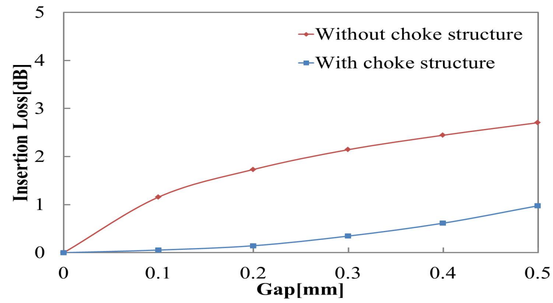


Fig. 7. Comparison of the losses depending on the gap *g*.

4. Conclusion

The choke structure on the metal plate with the waveguide was designed to suppress the loss due to the leakage from the gap between the substrate and the metal with the waveguide of microstrip-to-waveguide transition. Reducing the loss from the gap was confirmed from the improvement of the frequency characteristic and the electric field distribution.

References

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