Design of Via-less Planer Microstrip-to-waveguide Transition with Choke Structure

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1. Introduction

Millimeter-wave technologies have been developed for applications to high-speed wireless communication systems and high angular resolution microwave sensors. Figure 1 shows one of the possible configurations of the millimeter-wave RF module when a microstrip antenna is used. The microstrip-to-waveguide transitions are necessary at the connection of the waveguide with the antenna feed and with the planar RF circuit. We have developed planer microstrip-to-waveguide transitions on a single-layer dielectric substrate in the millimeter-wave band [1], [2]. Via holes surround a rectangular waveguide to prevent leakage of parallel plate mode transmitting in the substrate. However, an additional process for via holes increases production cost and manufacturing errors of via-hole positions increases insertion loss of the transitions. Then, we have proposed a choke structure for replacement from via-hole arrangement [3]. The size of the waveguide short pattern composed of the metal plate on the substrate is designed to form choke structures in the substrate around the waveguide. The impedance of the open circuit with a quarter wavelengths transmission line is equivalent to the short circuit. Therefore, the impedance at the point along the waveguide profile is equivalent to the short circuit, when the open circuit at the edge of the metal plate is spaced by a quarter wavelengths from the waveguide profile in the substrate. First, the planar microstrip-to-waveguide transition is designed. Then, we optimized the choke structure for the transition in this work. The perturbed characteristics of the transition are discussed and the simulated performance is presented in this paper.

2. Configuration of Via-less Planar Transition

Planar microstrip-to-waveguide transitions are designed in the millimeter-wave band. One is a conventional transition with via-holes, and another one is a proposed transition with choke structures for replacement from the via-holes used in the conventional transition. The configurations of the transitions are shown in Figs. 2 (a) and (b). A single layer dielectric substrate is attached to the waveguide open end (WR-12, 3.1 x 1.55 mm). The microstrip line is inserted into the waveguide short on the upper plane of the dielectric substrate. The electric current on the microstrip line couples to the matching patch in the aperture on the lower plane of the dielectric substrate. The electromagnetic wave radiates from the patch into the waveguide. The dielectric material of the substrate is Fluorocarbon resin film (thickness t = 0.127 mm, relative dielectric constant ε_r = 2.2 and dielectric loss tanδ = 0.001).

To prevent leakage of parallel plate mode transmitting in the substrate, via holes surround the waveguide in the substrate of the conventional transition shown in Fig. 2 (a). On the other hand, the via-hole arrangement is replaced by choke structure in the substrate of the proposed transition shown in Fig. 2 (b). The size of the metal pattern on the substrate is designed to be finite as p x q. The end of the metal pattern works for open circuit of the parallel plate waveguide. The impedance at the point along the waveguide profile is equivalent to the short circuit of the parallel plate waveguide, when the open circuit at the edge of the metal plate is spaced by approximately a quarter wavelengths from the waveguide profile. Cross-sectional views and major parameters of the proposed microstrip-to-waveguide transition are shown in Fig. 3. The choke length C, which is the spacing between the edge of the metal plate and the via-hole arrangement of the conventional transition, is optimized by electromagnetic simulation.

3. Simulated Characteristics

The planar microstrip-to-waveguide transitions on the single layer dielectric substrate are numerically analyzed by using the electromagnetic simulator HFSS. The performance of the via-less transition is compared with that of the conventional transition with via-holes. In the design of both transitions, the patch length L and the insertion length ρ of the microstrip line are optimized to minimize the reflection S_{11} at the design frequency. Furthermore, as for the proposed transition, the choke length C from the edge of the waveguide short pattern to the via-hole arrangement of the conventional transition is also optimized by the analysis. Optimized major parameters are listed in Table 1. The some values of the common parameters; patch length L, width W, and insertion length ρ are used in both transitions. The simulated S_{11} and S_{21} of both transitions are shown in Fig. 4. Single resonance was confirmed in the proposed transition as well as the conventional transition. The bandwidths of the conventional and the proposed transitions for S_{11} less than −20dB are 2.3 and 2.1 GHz, respectively. On the other hand, the resonant frequency 74.6 GHz of the proposed transition shifts by 3.0 GHz from the resonant frequency 77.6 GHz of the conventional transition. To investigate the effect for the shift of the resonant frequency, the variation of the reflection characteristic $S_{11,}$ when the length C of the choke structure changes, is investigated by simulation, as shown is Fig. 5. The resonant frequency shifts to lower, as the length C of the choke structure increases. Consequently, it is found that the shift of the resonant frequency can be compensated by changing the length C of the choke structure.

4. Conclusion

The via-less planer microstrip-to-waveguide transition on the single layer dielectric substrate is designed in the millimeter-wave band. Almost comparable performance is obtained without via-holes by using the choke structure. The 3 GHz frequency shift is observed in the simulation. However, this effect can be compensated by changing the choke length.

References

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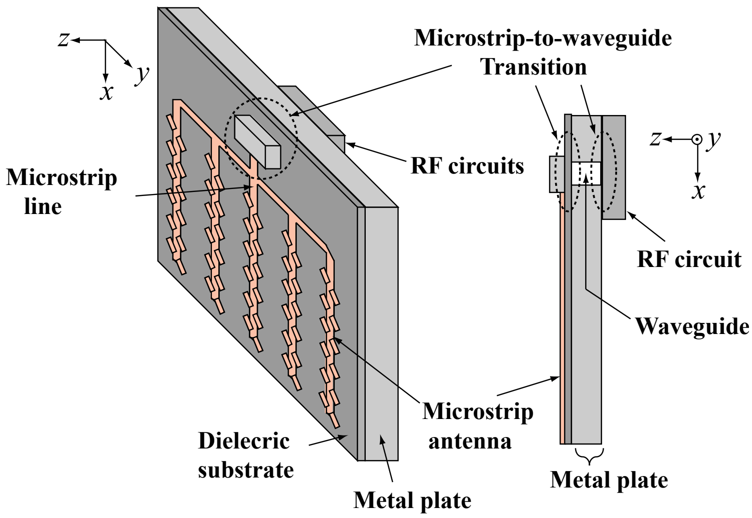

Fig. 1 Millimeter-wave RF module

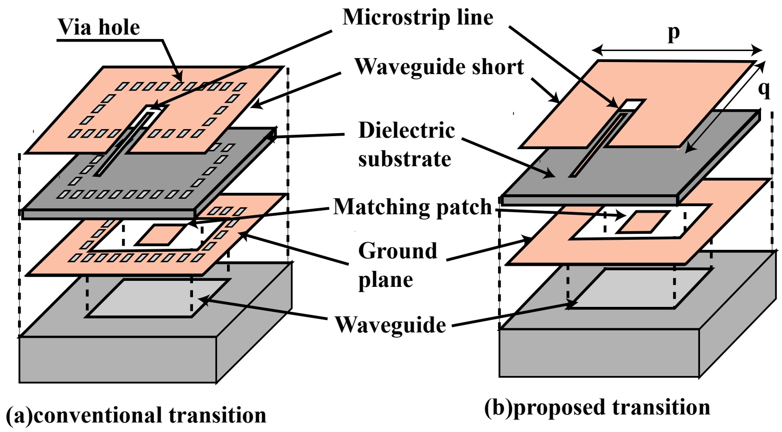

Fig. 2 MS-WG transitions fabricated on a single layer dielectric substrate

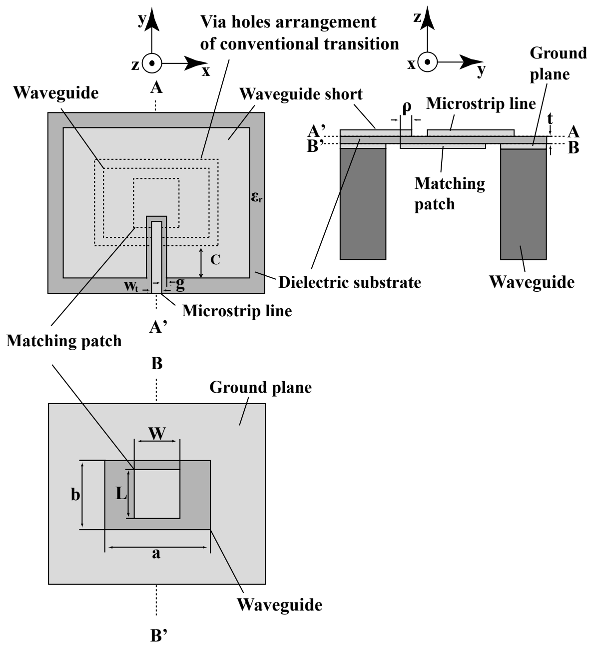

Fig. 3 Cross-sectional views and major parameters of via-less planer MS-WG transition on a single layer dielectric substrate

Table 1 Optimized major parameters

Major parameters	proposed transition	conventional transition
L[mm]	1.1	1.1
W[mm]	1.1	1.1
ρ[mm]	0.2	0.2
C[mm]	0.91	—

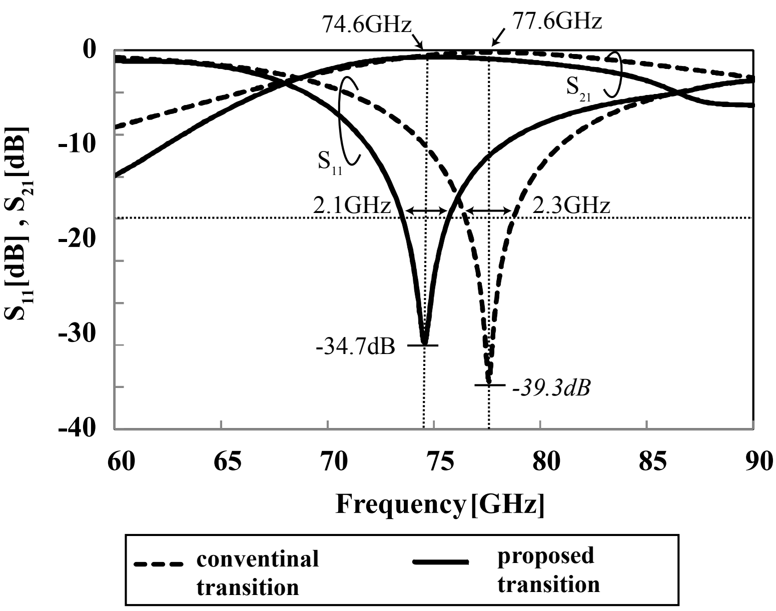

Fig. 4 S_{11} and S_{21} of via-less transition and transition with via-holes

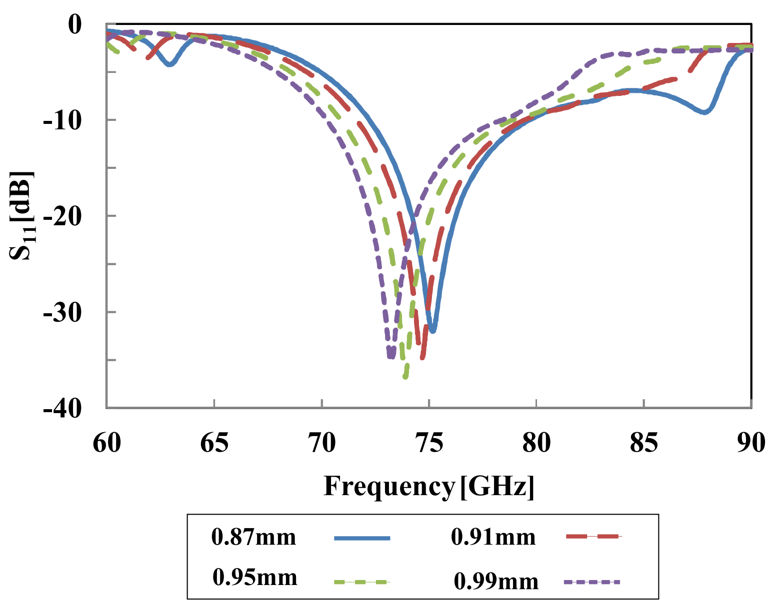

Fig. 5 Reflection characteristics versus choke length *C*