A Design of 79 GHz Band Coaxial Waveguide Transition using Finline Built on High-Permittivity Substrate

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***Abstract*—We have put a lot of effort into development of a 79 GHz band range finder and have seen that a coaxial waveguide transition using a finline built on a high-permittivity substrate is required. Then, we attempted to design a 79 GHz band coaxial waveguide transition using finline built on alumina substrate (relative permittivity 10). The goal of the performance is less than -10 dB of | S_{11} | at the frequency from 74 GHz to 84 GHz. In this paper, we focus on the gap between the outer side curves of the finlines. As a result, we have found that the gap between the outer side curves of the finlines has the optimal value. At the moment, based on the optimal value, we are producing the coaxial waveguide transition using finline.**

I. Introduction

In recent years, for various reasons, the demand for millimeter wave range finders and the microwave range finders has been increasing. In particular we are putting a lot of effort into development of a 79 GHz band range finder. The 79 GHz band has already been legislated in Europe. However, in Japan, it has not been legislated yet (as of November 2012). We are developing a 79 GHz band range finder, foreseeing that the 79 GHz band will be approved for use from now on. The allowable occupancy frequency bandwidth of the 79 GHz band will be wider than that of the 60 GHz band or 76 GHz band, which are legislated already in Japan. This is an important advantage in the performance of range-finding.

In development of the 79 GHz band range finder, we find that the coaxial waveguide transition using a finline which is built on a high-permittivity substrate is required. Typically, the finline is built on a low-permittivity substrate to obtain broadband characteristics. This is because, it is difficult to realize broadband circuits on a high-permittivity substrate. Meanwhile, to avoid loss of signal, millimeter wave circuits are normally built on a high-permittivity substrate such as alumina. If the relative permittivity of the substrate of the coaxial waveguide transition and that of the millimeter wave circuit are different, a reflected signal may emerge at the connection point. Therefore, it is preferable that the coaxial waveguide transition and the millimeter wave circuit are built on the same substrate.

Due to this, we attempted to design a 79 GHz band coaxial waveguide transition using finline built on the high-permittivity substrate alumina (relative permittivity 10). A goal of the performance is less than -10 dB of | S_{11} | at the frequency from 74 GHz to 84 GHz.

II. A Structure of the Coaxial Waveguide Transition Using Finline

Coaxial waveguide transition refers to the circuit which connects the coaxial line and wave guide by changing the mode of propagation. Since a mixed system of coaxial and waveguide is a common configuration for microwaves and millimeter waves, the coaxial waveguide transition is a critical part. An example of the structure of the coaxial waveguide transition using finline is shown in Fig. 1.

It has a form where the dielectric substrate of thickness t and relative permittivity ε_r is put into the space of waveguide tube, as shown also in Fig. 1. The value of a standard waveguide is used for the value of X and Y.

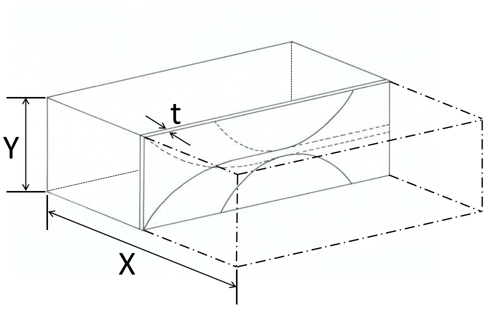

Fig. 1. A structure of the coaxial waveguide transition using finline

III. Design

A. Design condition

We design the coaxial waveguide transition with the goal of performance less than -10 dB of | S_{11} | at the frequency from 74 GHz to 84 GHz. A waveguide, WRI-740 [X:3.099 mm, Y:1.549 mm], which is designed for a frequency band of 60.5 GHz 91.9 GHz, is used. The finline pattern is mounted on the dielectric substrate alumina which has a relative permittivity of 10 and a thickness of 0.1 mm.

As shown in Fig. 2, the length of the finline part is 3.2 mm and that of the microstrip line part is 4 mm. In this paper, the two curves that are found in the outline of the finline are named the outer side curve and the inner side curve, respectively.

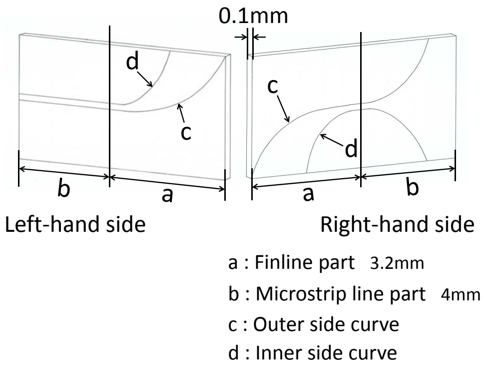

Fig. 2. Design of coaxial waveguide transition using finline

B. Design approach

It is considered that the characteristics of the finline part depend on the whole form of the finline, such as its size and outline. In this approach, we focus on the gap between the outer side curves of the finlines. However, other parameters are fixed. The gap g is changed every 0.02 mm from +0.1 mm to -0.38 mm and S_{11} is calculated by FEM analysis (see Fig. 3). For FEM analysis, EMPro made by Agilent is used.

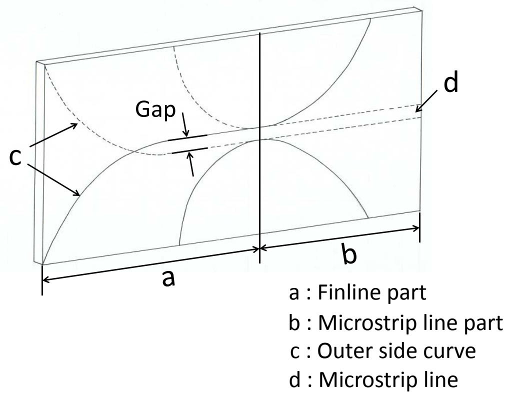

Fig. 3. Gap g

The typical characteristics of S_{11} are found for four cases: g=+0.1 mm, 0 mm, -0.14 mm and -0.38 mm. Corresponding to these cases, the form of the finline and S_{11} are shown in the following section.

C. Form of the finline and S_{11}

1) Case of g=+0.1 mm: The form of the finline for g=+0.1 mm is shown in Fig. 4.

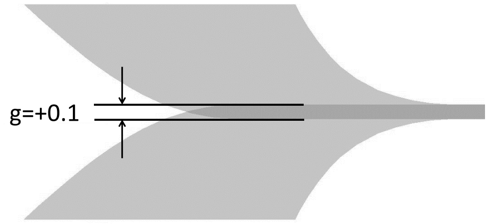

Fig. 4. Finline(g=+0.1)

The trajectory of S_{11} plotted on a smith chart is shown in Fig. 5, and $|S_{11}|$ is shown in Fig. 6.

We can see that the magnitude of the reflection coefficient $|S_{11}|$ is large because the trajectory of S_{11} shown in Fig. 5 is distant from the center of the smith chart. Specifically, as shown in Fig. 6, $|S_{11}|$ is more than -10 dB over the whole frequency range.

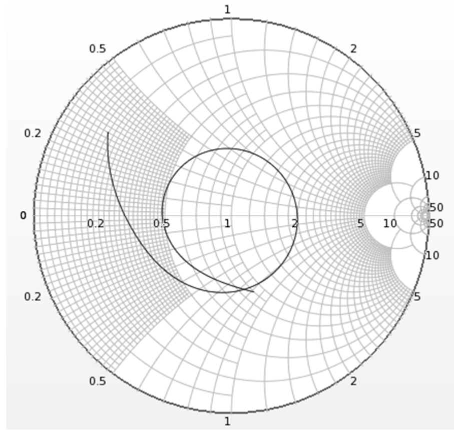

Fig. 5. S_{11}(g=+0.1)

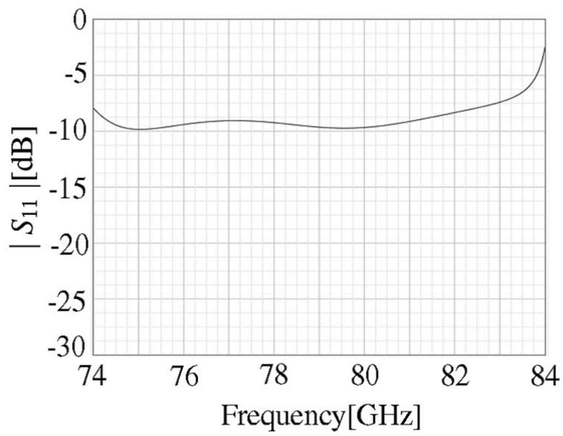

Fig. 6. $|S_{11}|$(g=+0.1)

2) Case of g=0 mm: The form of the finline for g=0 mm is shown in Fig. 7.

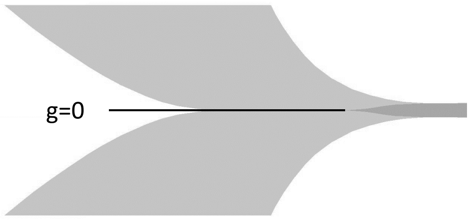

Fig. 7. Finline(g=0)

The trajectory of S_{11} and $\mid S_{11} \mid$ are shown in Fig. 8 and Fig. 9, respectively.

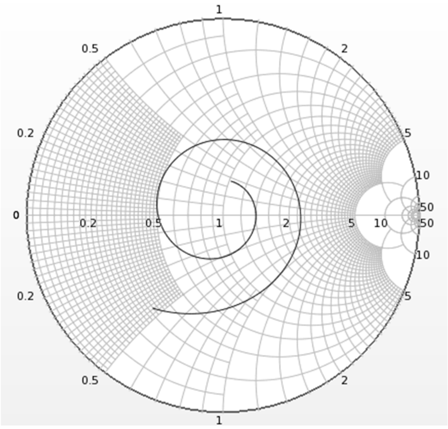

Fig. 8. $S_{11}(g=0)$

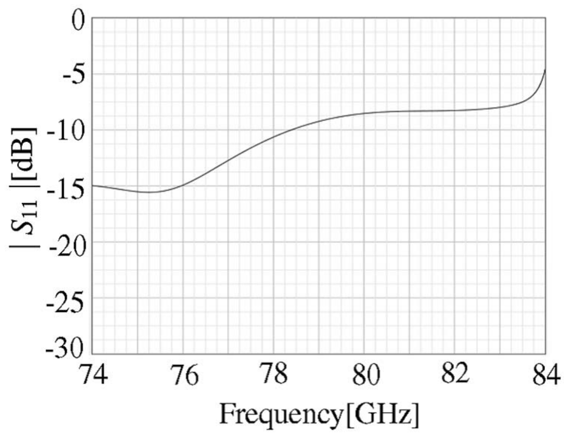

Fig. 9. $\mid S_{11} \mid(g=0)$

$\mid S_{11} \mid$ is more than -10 dB if the frequency is over 78 GHz.

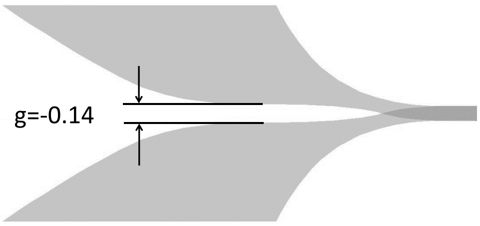

Fig. 10. Finline(g=-0.14)

3) Case of g=-0.14 mm: The form of the finline for g=-0.14 mm is shown in Fig. 10.

The trajectory of S_{11} and $\mid S_{11} \mid$ are shown in Fig. 11 and Fig. 12, respectively.

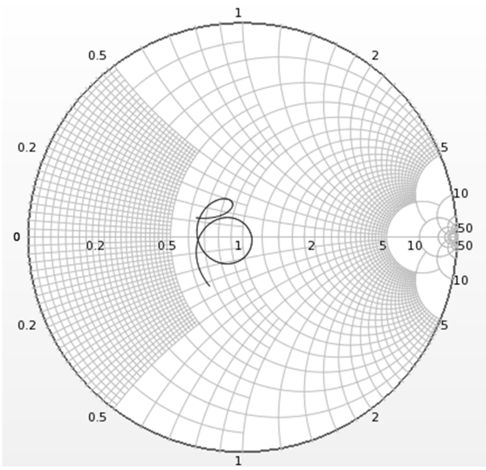

Fig. 11. $S_{11}(g=-0.14)$

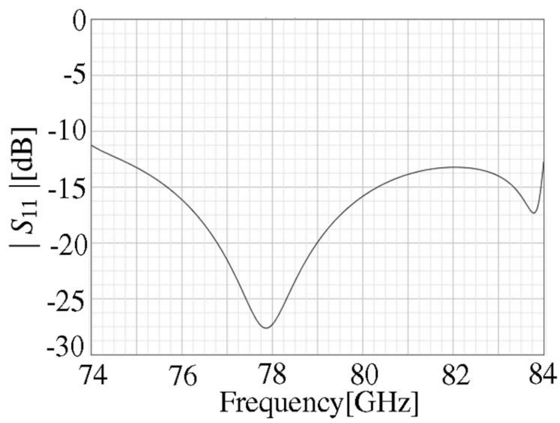

Fig. 12. $\mid S_{11} \mid(g=-0.14)$

We can see that $\mid S_{11} \mid$ is small because the trajectory of S_{11} converges near the center of the smith chart all around.

Specifically, as shown in Fig.12, $\mid S_{11} \mid$ is less than -10 dB over the whole frequency range.

4) Case of g=-0.38 mm: The form of the finline for g=-0.38 mm is shown in Fig. 13.

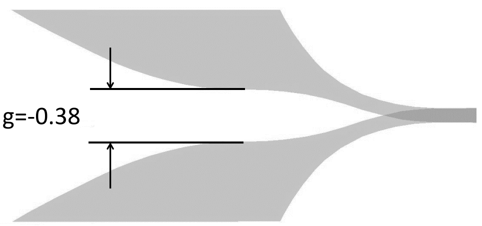

Fig. 13. Finline(g=-0.38)

The trajectory of S_{11} and $\mid S_{11} \mid$ are shown in Fig. 14 and Fig. 15, respectively.

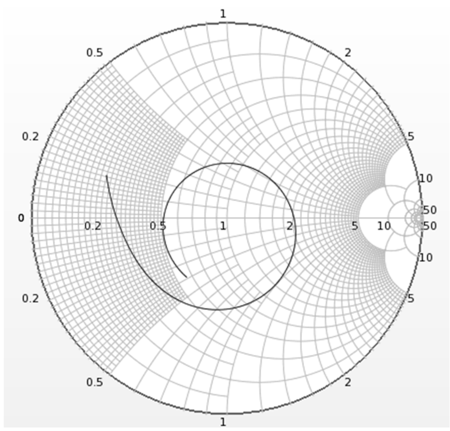

Fig. 14. S_{11}(g=-0.38)

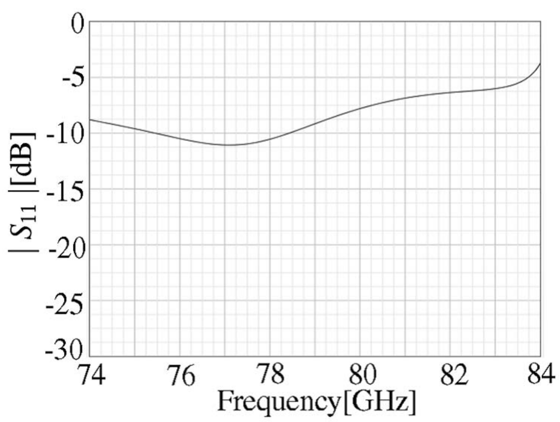

Fig. 15. $\mid S_{11} \mid$(g=-0.38)

The trajectory of S_{11} shown in Fig. 14 is distant from the center of the smith chart. $\mid S_{11} \mid$ is more than -10 dB except for near 77 GHz.

IV. Conclusions

In this design, we focused on the gap between the outer side curves of the finlines. As a result, the optimal gap is g=-0.14 mm. Under this condition, $\mid S_{11} \mid$ is less than -10 dB over the whole frequency range (from 74 GHz to 84 GHz). Here, the microstrip line part and the inner side curve of the finline are fixed. In the future, we will examine how these fixed parts influence the performance of the coaxial waveguide transition using the finline.

At the moment, based on the optimal value, we are producing the coaxial waveguide transition using finline. We will unveil that on the day.

References

[1] George E. Ponchak and Alan N. Downey, "A New Model for Broadband Waveguide to Microstrip Transition Design," National Aeronautics and Space Administration Lewis Research Center, December 1986.

[2] Kruger, J. C., "Finline and coaxial line to waveguide transitions at X-band," Communications and Signal Processing, 1998, COMSIG '98. Proceedings of the 1998 South African Symposium on, pp. 401-406, 7-8 Sep 1998.