An Electroplated 3D Printed Waffle Type Waveguide for Ku-Band Application

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***Abstract*— In this paper, we report an electroplated 3D printed waffle type waveguide for submillimeter wave application. We designed the waffle type waveguide for Ku-band application. The waffle type waveguide consists of a waveguide part and two low pass filter parts for electromagnetic wave transmission and attenuation, respectively. In the fabrication, a fused deposition modeling (FDM) resin 3D printing technique was used to obtain low-cost device, and electroplating was performed to reduce transmission loss. By the S-parameter measurement, the operation of the waffle type waveguide was verified. We obtained reflection loss less than -20 dB, and the lowest insertion loss of -0.78 dB at frequencies from 16.7 GHz to 19.7 GHz.**

I. Introduction

RECTANGULAR waveguides are widely used as an electromagnetic wave transmission component in microwave or millimeter wave circuits because they are easy to handle and have low insertion loss characteristics. Conventionally, rectangular waveguides are fabricated by CNC milling technique. However, as the frequency increases, the size of the waveguide becomes small, an increase in manufacturing time and cost, machining is difficult for severe dimensional tolerances. In addition, susceptible to machining accuracy such as flatness and surface roughness, attenuation occurs. As an alternative method of fabricating the waveguide for millimeter wave band or higher band, a 3D printing technique has been paid attention [1].

Previously we proposed the waffle type waveguide that is one of non-contact waveguides tolerable to fabrication and assembly accuracies [2]. Waffle type waveguide is made by assembling two upper and lower conductive plates. The overview of the waffle type waveguide is shown in Fig.1. As shown in Fig1(a), the waffle type waveguide is composed of electromagnetic wave transmission part and low pass filters. The low pass filter consists of periodically arranged waffle-like structure and the bosses of upper and lower plates are arranged at a constant distance as shown in Fig1(b). The low pass filter cuts off frequencies lower than to be transmitted frequencies and consequently electromagnetic waves having higher frequencies than cut off frequency are confined in rectangular part and transmitted. While the conventional rectangular waveguides are a conductor on the wall, the waffle type waveguide is an impedance wall. Therefore, it is possible to reduce the influence of processing accuracy, such as flatness and surface roughness in the wall, it is possible to low transmission loss.

In this paper, we propose a fabrication method to obtain a low-cost and low transmission loss waffle type waveguide.

II. Fabrication and Measurement Results

To obtain a low-cost and low transmission loss waffle type waveguide, we used a fused deposition modeling (FDM) resin 3D printing technique and Ag electroplating for fabrication.

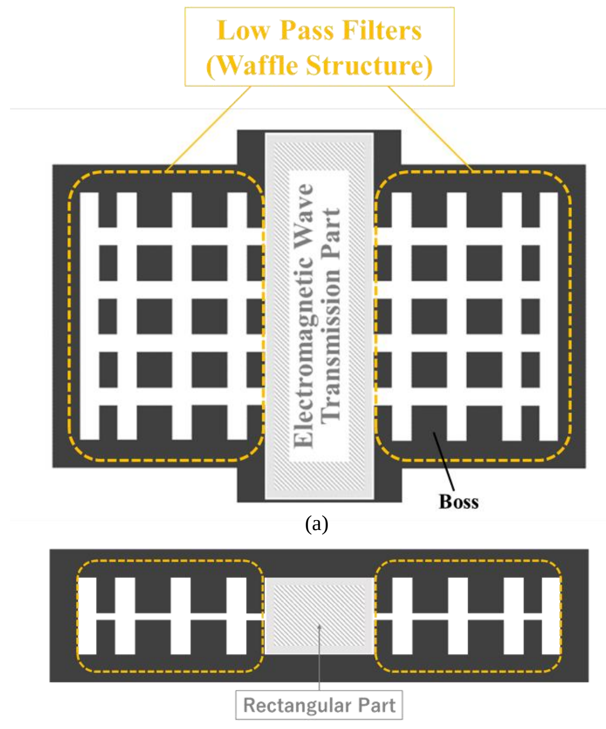

Fig. 1. Overview of the waffle type waveguide (a)internal structure of the waffle type waveguide, (b) cross sectional view of the waffle type waveguide.

First, we fabricated the waffle type waveguide using FDM resin 3D printer. The surface roughness of the device modeled by the FDM resin 3D printer is very large because the stacking marks remain during modeling. Since the surface roughness of the electromagnetic wave transmission part has a influence on the transmission characteristics, surface treatment was performed. After that Ag electroplating($10\mu m$) was performed to reduce transmission loss. As shown in Fig.2, the surface roughness after modeling was $3.36\mu m$, but it decreased to $0.58\mu m$ after Ag electroplating.

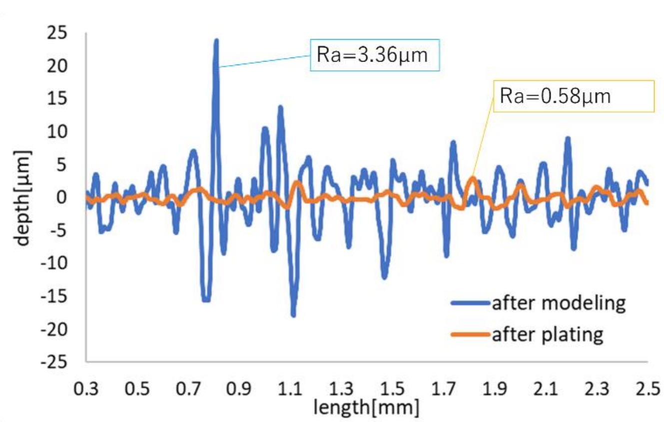

Fig. 2. Comparison of surface roughness after modeling and Ag electroplating

The waffle type waveguide manufactured by FDM resin 3D printing technique is shown in the Fig. 3(a), and the waffle type waveguide after Ag electroplating is shown in Fig. 3(b). Black and white colored parts in Fig. 3(a)(b) represents 3D printed resin and Ag electroplated film, respectively. Two components are fabricated and assembled. The measuring flange is integrated with waffle type waveguide. To measure S-parameters, waffle type waveguide was assembled and connected to network analyzer as shown in Fig. 3(c).

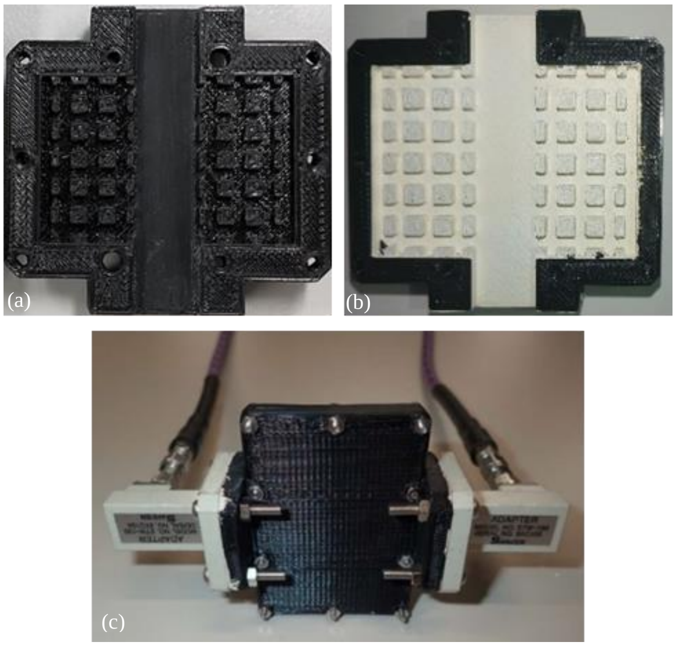

Fig. 3. (a) A photograph of the fabricated waffle type waveguide using a 3D resin printing and electroplating, (b) A photograph of assembled waffle type waveguide and measurement setup.

The measurement results are shown in Fig.4, which are compared with simulation ones. The measurement results roughly agreed with the simulation ones. At frequencies from 16.7 GHz to 19.7 GHz, we achieved reflection loss less than -20 dB, and the lowest insertion loss of -0.78 dB.

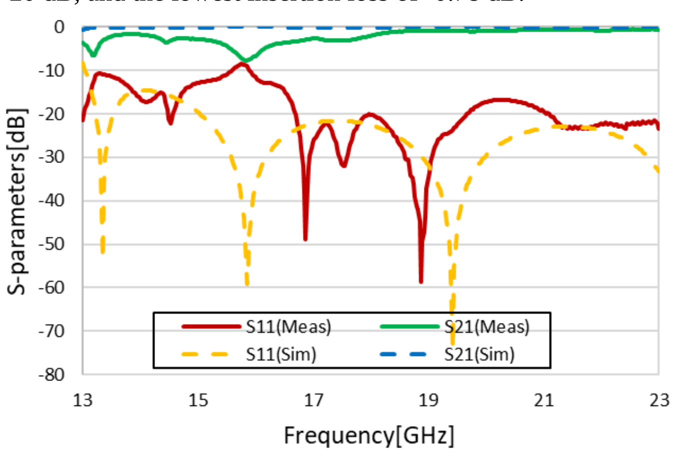

Fig. 4. S-parameter measurement results; solid line and dashed line represents measurement results and simulation results, respectively.

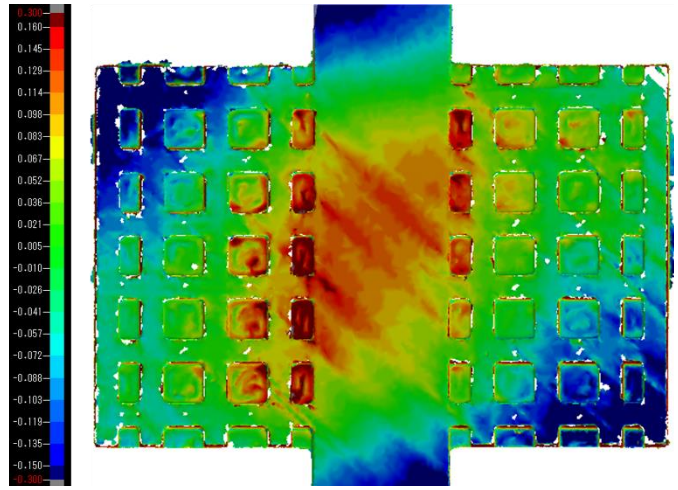

Fig. 5. Comparison of designed STL data and shape measurement results of the waffle type waveguide manufactured by FDM resin 3D printing technique

III. Conclusion

In this paper, we proposed a low-cost and low transmission loss waffle type waveguide for Ku-band application. In fabrication, FDM resin 3D printing and Ag electroplating were used to achieve low-cost and low transmission loss, respectively.

In the S-parameter measurement, we confirmed that the measurement results roughly agreed with the simulation ones. We achieved reflection loss less than -20 dB, and the lowest insertion loss of -0.78 dB at frequencies from 16.7 GHz to 19.7 GHz. At frequencies from 14 GHz to 16.7 GHz, the transmission losses are high. It caused from electroplating film bad uniformity and not concrete connection between waveguide and ports of network analyzer due to high 3D printed resin surface roughness. Furthermore, it may be affected by warpage during device modeling. Fig.5 shows a comparison between the designed STL data and the shape measurement results of a waffle type waveguide manufactured by FDM resin 3D printing technique. As you can see from the Fig.5, the central red part is raised and the blue part at the edge is lowered. It is considered that these distortions affect the transmission characteristics in some frequency bands.

References

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[2]. K. Itagaki and S.-S. Lee, “Fabrication and evaluation of a waffle type waveguide for Ka-band application”, *Proc of EuMC 2018*, pp. 675-678, 2018.