Excitation of a Longitudinal Slot on a Hollow Rectangular Coaxial Line by Metal Support of the Inner Conductor

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Abstract

This paper presents the excitation of a longitudinal slot on a hollow rectangular coaxial line by a metal support between two conductors and the fabrication by diffusion bonding of laminated metal thin plates. The measured loss of a straight line is 0.046dB/cm at 60GHz while the simulated one is 0.043dB/cm.
Keywords : rectangular coaxial line, metal support, longitudinal slot, diffusion bonding

1. Introduction

A rectangular coaxial line is a TEM transmission line, which has constant group delay over frequency and has a smaller size than a rectangular waveguide. By adopting a rectangular coaxial line to feed a slot array, the group delay characteristic can be improved and the size can be reduced in comparison with an array on a rectangular waveguide. However, the transmission loss of the rectangular coaxial line will increase by the size reduction.

A linear array of a small number of slots can have stable operation by laminating several metal plates and screwing them at both ends to form a coaxial line without supporting the inner conductor because currents on the conductors mainly flow along the coaxial line [1]. However, support for the inner conductor and perfect electrical contacts among the laminated metal plates will be required for a longer linear array and a planar array. The diffusion bonding [2] will be adopted for this requirement. This paper demonstrates the simulated and the measured results of a support for the inner conductor and a longitudinal slot on a hollow rectangular coaxial line in the 60GHz band.

2. Rectangular Coaxial Line and Excitation of a Longitudinal Slot

In a rectangular coaxial line the operational frequency has to be below the cutoff frequencies of all the higher-order modes. We determine the dimension of the rectangular coaxial line for the 60 GHz band. We select the cutoff frequency of the first higher-order mode of 70GHz and the characteristic impedance of 50Ω for the dominant mode. The height has to be a multiple of the thickness of the plate. We compute the cutoff frequencies by FDTD method [3] and the characteristic impedance by conformal mapping [4]. Figure 1 depicts the structure of the designed rectangular coaxial line, which gives the cutoff frequency of the first higher-order mode of 68.8GHz and the characteristic impedance of 50.8Ω.

Support for an inner conductor is needed due to the hollow structure of a long coaxial line. We consider support structures to connect an inner and outer conductors. To suppress the reflection, two supports are placed with suitable spacing to minimize the reflection at 60GHz. Ansoft HFSS is utilized for analyzing the support structures. The designed support pair is shown in Figure 2. The bandwidth of the reflection less than −20dB is 17% in the simulation.

As mentioned in the introduction, currents on the conductors flow in the direction of a coaxial line; therefore, a longitudinal slot on the coaxial line cannot be excited. To make current cross the longitudinal slot, a support structure is placed underneath the slot, which changes the current flow. For the reflection-suppression, another support is placed in front of the slot-excited support. The spacing of the two supports is chosen to minimize the reflection at 60GHz. Figure 3 shows the designed longitudinal slot with 2.65mm. This slot gives 3.7% bandwidth for the reflection less than −20dB and the coupling more than 35% in that bandwidth in the HFSS simulation.

3. Fabrication and Measurement

We fabricate the structures with different line lengths and intervals of the support pairs on rectangular coaxial lines by diffusion bonding of laminated thin copper plates. Some rectangular coaxial lines are used to measure the flatness and the extension of the inner conductors by removing layers 1 and 2 after the bonding.

In order to estimate the maximum interval of the support pairs keeping the flatness of the inner conductor, we measure the lines of the support pairs with various intervals. The transmission coefficient degrades with the interval more than 10mm at which we confirm the deformation of the inner conductor presumably caused by the thermal expansion in the fabrication process.

The transmission loss of the rectangular coaxial line is evaluated by measuring different lengths of the lines. The measured loss includes not only the loss of the rectangular coaxial line but also those of the support of the inner conductor and the transitions. We evaluate the inherent loss of the rectangular coaxial line by subtracting the loss of the supports and the transitions computed by HFSS from the measured data. The extracted losses are plotted as a function of the line length as shown in Figure 4. The slope of the fitting linear line gives the transmission loss per unit length (dB/cm). The measurement gives 0.046dB/cm at 60GHz while the HFSS simulation gives 0.043dB/cm. The measured loss of the rectangular coaxial line is approximately three times larger than the standard rectangular waveguide WR-15 (0.015dB/cm); however, the loss is still smaller than the loss of a microstrip line of 0.24dB/cm [4]. The measured result shows that transmission loss does not increase due to the fabrication.

Figure 5 shows the reflection coefficient of the support pair in Figure 2. Since the measured result includes the characteristic of the transitions, it is compared with the full model simulation by HFSS. A good agreement is achieved. The characteristic of the support pair is indirectly confirmed.

The reflection coefficient of the single longitudinal slot in Figure 3 is shown in Figure 6. A full-model HFSS simulation including the transition is performed as well. Figure 7 shows the coupling calculated from the reflection and the transmission coefficients. As can be seen in Figure 7, the measured coupling is higher than the simulation data because the measured transmission coefficient is smaller due to the loss of the transition. Although the full-model simulation gives the same tendency as the measured data, the frequency shift of about 1.5 GHz is observed in the same way as the reflection characteristic in Figure 6. The slot length correction could be required for compensating the frequency shift. Figure 8 shows the radiation pattern of the slot in Figure 3. The measurement is performed in an anechoic chamber. The slot is placed near the center of the ground plane with the size of 75mm×150mm. The measured data is compared with the calculated data including diffraction from the edge of the ground plane [6]. They have good agreement to each other.

4. Conclusion

In this paper, we have demonstrated the support for the inner conductor and the excitation of a longitudinal on a hollow rectangular coaxial line in the 60GHz band. The proposed structures on a rectangular coaxial line were fabricated by diffusion bonding of laminated thin copper plates and the measured results have been shown. The good agreements between the measured and the simulation results have been obtained except the shift of the operational frequency of the longitudinal slot. We will consider the bandwidth enhancement of the reflection of the support and the configuration of a two-dimensional slot array as the future studies.

References

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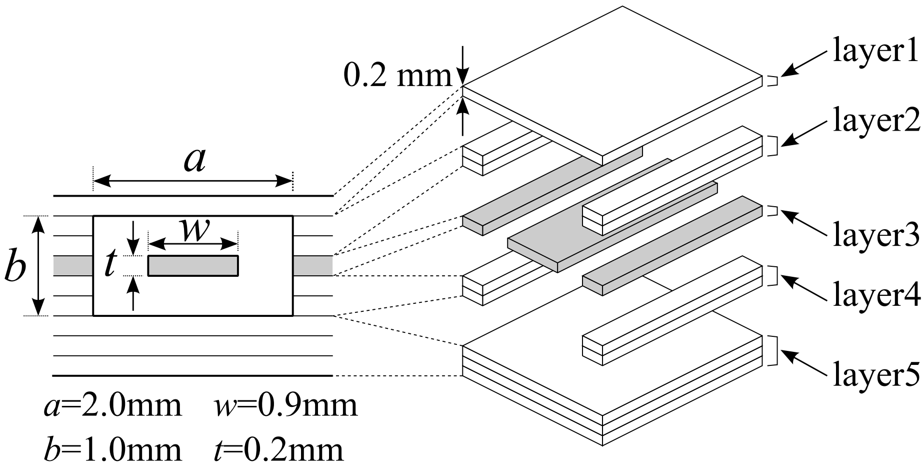

Figure 1: Rectangular coaxial line of laminated metal plates

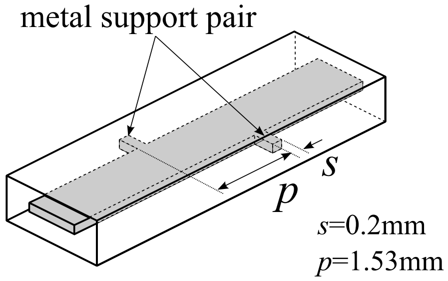

Figure 2: Support pair for an inner conductor

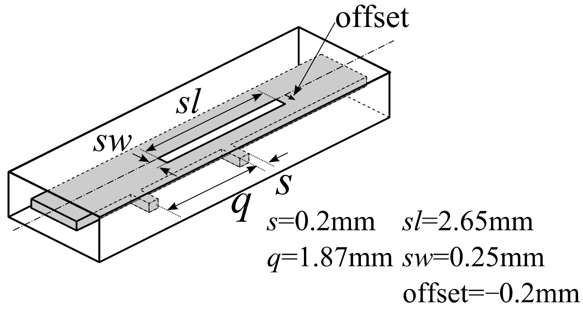

Figure 3: Longitudinal slot

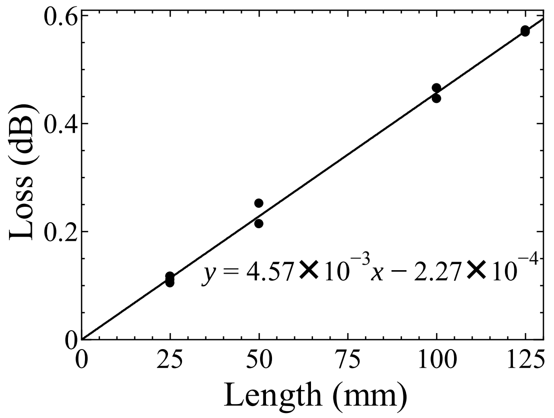

Figure 4: Transmission loss of the rectangular coaxial line

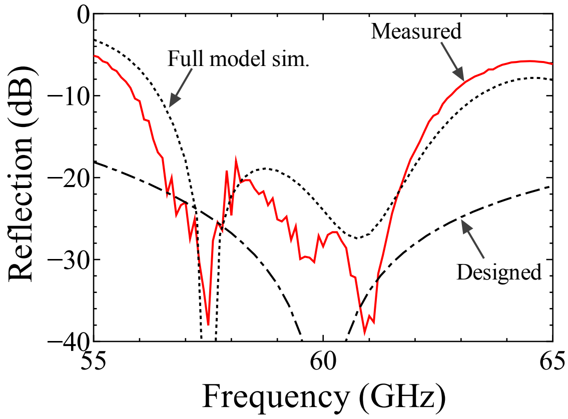

Figure 5: Reflection of the support pair for the inner conductor

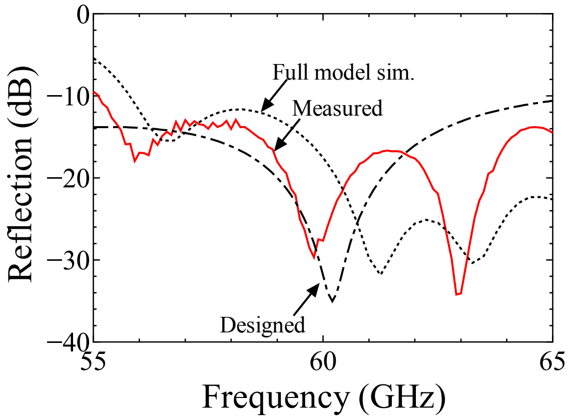

Figure 6: Reflection of the slot

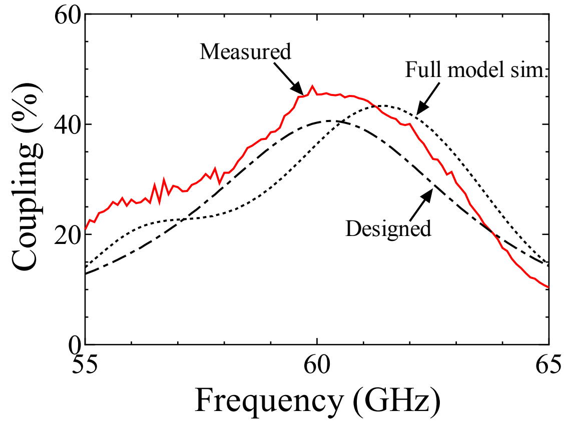

Figure 7: Coupling of the slot

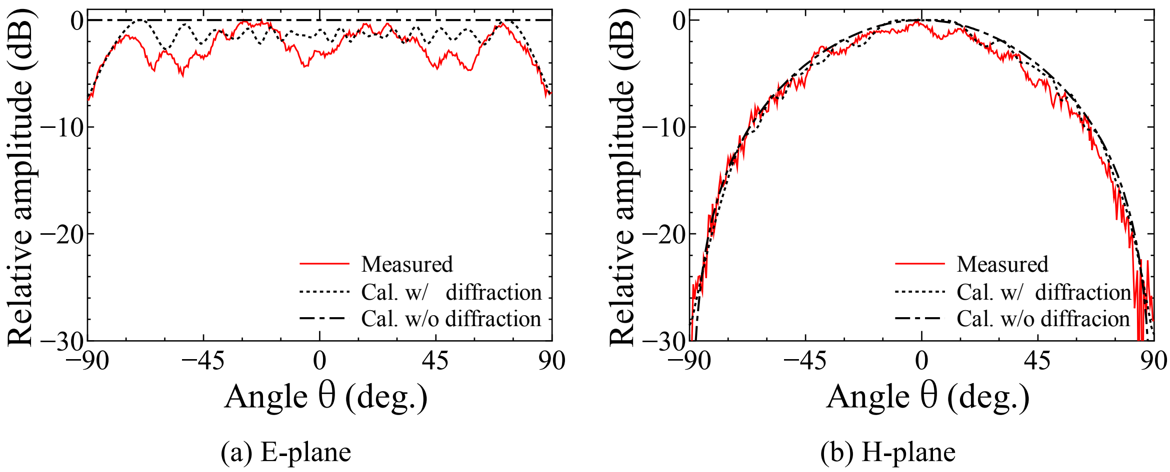

Figure 8: Radiation pattern of the slot