DEVELOPMENT OF THE "LAMINATED WAVEGUIDE"

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Abstract

A new waveguide structure for millimeter wave has been developed. It is a dielectric waveguide, with conductor walls consisting of two lined via-holes , herein referred to as the "laminated waveguide." Applications for the laminated waveguide include antenna feed lines.

Introduction

Recently, systems in the range of millimeter wave frequencies, such as collision avoidance radar or wireless LAN, have attracted much attention. The development of such devices are advancing rapidly. These devices are mounted on circuit boards or packages, and are connected to antennas at the end of circuits. Microstrip lines which are placed on the surface of circuit boards are mainly used. For feed lines of antennas, especially for feed lines of small size array antennas, inner lines are needed. The typical inner line is a triplate line. It is well known, however, that parallel plate modes occur at the discontinuous areas of triplate lines. This phenomenon is the major obstacle in the development of high performance antennas. The authors have invented a new transmission line structure which has low losses and easy design methods for bending, branching, power dividing, and other functions. The new transmission line is manufactured using lamination technologies, consequently it is named the laminated waveguide.

The structure of the laminated waveguide

Waveguides have the best transmission characteristics among many transmission lines. Waveguides, however, are impractical for circuit boards and packages for two major reasons: size and structure. Waveguides are surrounded by metal walls. Vertical metal walls are not able to be manufactured by lamination techniques familiar to the fabrication process of circuit boards or packages. Now, we have invented the laminated waveguide. The schematic

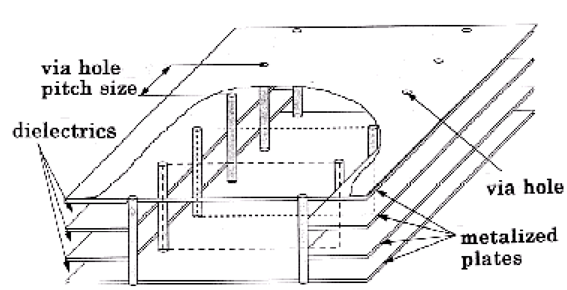

Figure 1. Laminated Waveguide

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diagram of the laminated waveguide is shown in Fig.1. Vertical planes of laminated waveguides consist of filled via holes and metallized planes. Waveguide structures can then be manufactured by lamination techniques, with the added benefit of reduction in size to traditional waveguides, by a factor of 1/(square root of k) (k: relative dielectric constant). Therefore, the laminated waveguide is able to compensate the defects of traditional waveguides and is expected to be suitable for feed lines of small size array antennas.

Electromagnetic simulation

Electromagnetic simulation is carried out under various conditions of via hole pitch size. HFSS(High Frequency Structure Simulator) was employed for the simulator. The electric field strength distributions of H plane at 60GHz is shown in Fig. 2. The via hole pitch size of condition A is 0.52mm, and condition B is 1.04mm. From Fig. 2, it is obvious that electromagnetic wave leakage through the gap of via holes in the B condition, but there is no leakage in the A condition. Electromagnetic waves should not leak with a via hole pitch smaller than a quarter wavelength.

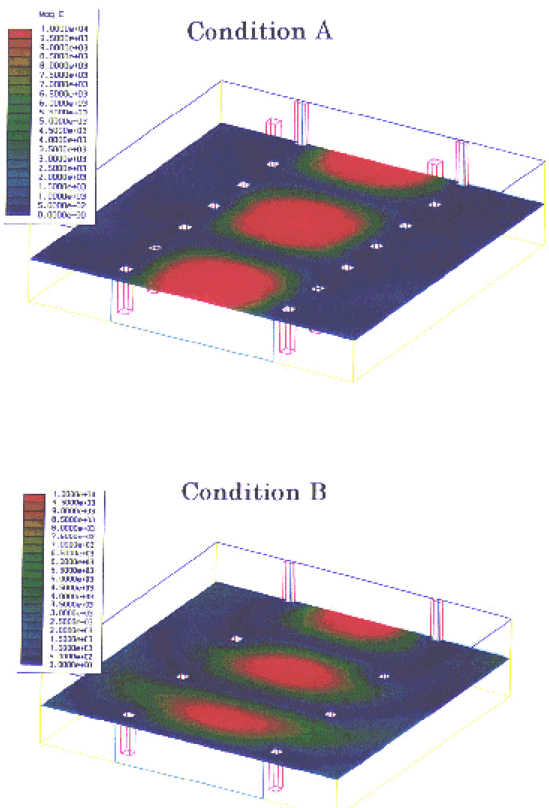

Figure 2. Electric Field Strength Distribution and Via Hole Pitch Size

Making a laminated waveguide as an experiment and measurement

Laminated waveguides are constructed as an experiment using glass-ceramics, which can be wired by copper metal. This glass ceramic is developed by Kyocera Corp. Its dielectric constant is 5.0 and its dielectric loss is 0.0008 at 60GHz. This laminated waveguide is composed of 4 layers; the cross section size is 1.2mm x 0.6mm; the parallel plates correspond to H planes of the waveguide. The diameter of the via hole is 0.1 mm and the size of via hole pitch is 0.26 mm. Feeding pins are used for the interconnection of circuits. The

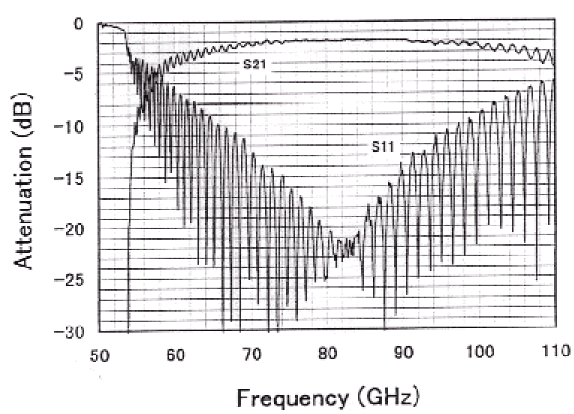

Figure 3. Transmission Characteristics

feeding pin is composed of 3 stacked via holes, its length is 0.45mm. The waveguide is straight and the distance of both feeding pins is 36.0mm.

Transmission characteristics of the above sample are shown in Fig. 3. It is found that signals transmit above 55GHz. This phenomenon is normal for waveguides. The cut off frequency of laminated waveguides is in good agreement with the calculated frequency.

It is also found that insertion losses are lower than 2dB and reflection is lower than -15dB over the wide range of 75GHz to 90GHz. The insertion losses per unit length is estimated to be lower than 0.4 dB/cm.

Basic unit for antenna feed lines

For antenna feed lines, isolation between lines is necessary, as well as basic units such as bend, branch, interconnection of upper/lower layer and so on. It is not easy to build up these basic units using triplate lines, but it is easy using laminated waveguides. To be certain to build up these units easily, electromagnetic simulation is carried out at 77GHz.

First, the result of isolation is shown in Fig. 4a. It is found to be well isolated between contacted lines. Isolation at 77GHz is lower than -20dB.

Next, the results of bend and branch are shown in Fig. 4b and Fig. 4c. It is found to be a good bend and branch. Reflections at 77GHz are lower than -15dB in both units.

Next, the simulation of interconnection between upper layer and lower layer is carried out by using the model shown in Fig. 4d. The reflection of interconnection at 77GHz is lower than -15dB.

It was verified that the laminated waveguide has low losses at discontinuous areas as opposed to the high loss observed for triplate lines.

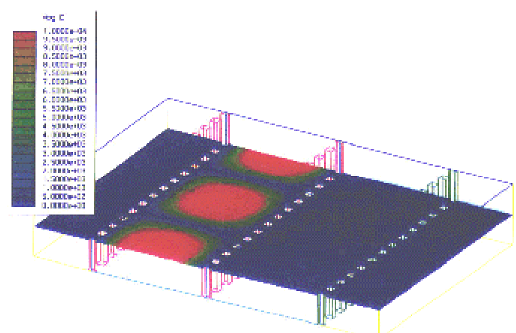

Figure 4a. solation Characteristics

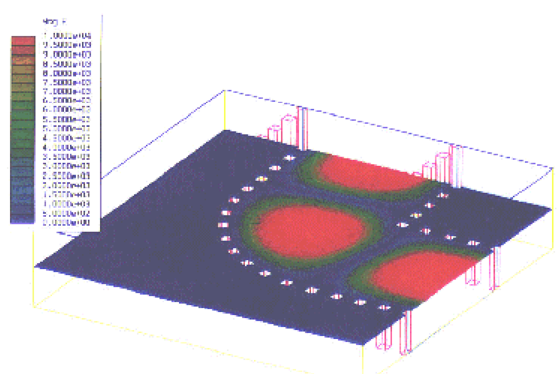

Figure 4b. Bend Structure and Electric Field Strength Distribution

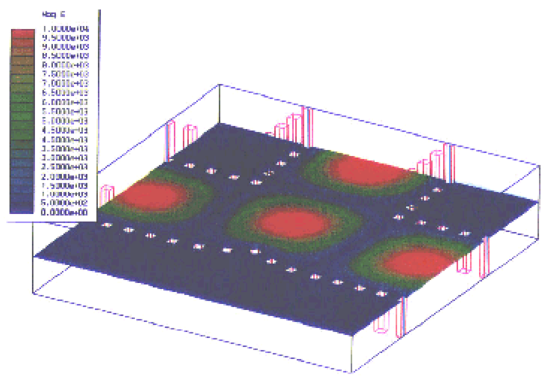

Figure 4c. Branch Structure and Electric Field Strength Distribution

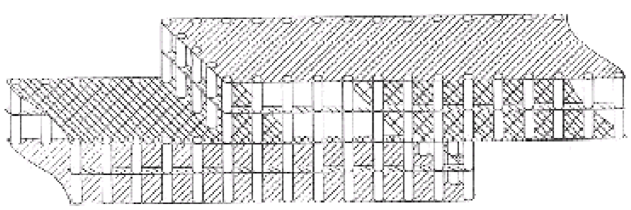

Figure 4d. Interconnection Structure

Conclusion

The laminated waveguide has been invented, enabling lamination technology in the fabrication of waveguides. Electromagnetic wave leakage is prevented by using side wall via hole pitch smaller than a quarter wavelength. According to this guideline, samples are designed and fabricated as an experiment using the newly developed low temperature co-firing glass-ceramics. The results show that the laminated waveguide has low loss, making it a high performance transmission line. Further more, the isolation between two lines has been checked, as well as basic units of bends, branches, interconnections between upper and lower layers, and power dividers. The results show good performance in every case.

According to all data above, the laminated waveguide is suitable for feed lines of a small size plane antenna array.