COP Millimeter-Wave Horn Array Antenna

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1. Introduction

Low cost and high performance millimeter-wave array antennas have been demanded in recent years due to increasing millimeter-wave applications in high-speed mobile communications, automobile collision avoidance radars, etc. Plastic waveguides, which are composed of hollow liquid crystal polymer (LCP) and plated copper, have been reported to reduce the cost [1,2], while array antenna system requests complex configuration that can not be realized by the structure.

This paper introduces a Cyclo-Olefin Polymer (COP) millimeter-wave horn array antenna which is manufactured by injection molding process. The antenna consists of a low loss dielectric waveguide covered by plated copper as shown in Fig.1. Our proposed antenna guides the electro-magnetic wave inside the dielectric, which is different from the LCP structure. COP was selected to reduce transmission loss. The cross-sectional size of the waveguide can be reduced by filling with dielectric, thereby enabling a dense layout of radiating elements. Therefore, a one-dimensional APAA can be realized by arranging this array antenna in the beam scanning direction. The antenna is composed of horns, grooved circular waveguide polarizers [3], E-plane T-junctions, and E-plane bends employing copper plated dielectric waveguides. This structure makes it possible to manufacture the feed circuit and radiating elements as an integrated unit by using injection molding [1,2] and can improve the mass-producibility of millimeter-wave antennas.

2. Components of Injection Molded Horn Array Antenna

2.1 Straight Line

Fig.2 shows the structure of a copper plated dielectric waveguide. The waveguide is manufactured by the injection molding. In the molding manufacturing process, in order to take the dielectric waveguide parts out of a metallic mold smoothly, the draft angle of the waveguide wall is inevitable. For this reason, the waveguide transverse section becomes hexagonal shape. The draft angle of the waveguide wall is 1.0 deg, the width of waveguide is 3.08mm, the height of the waveguide is 1.13mm, and the thickness of copper plating is about 10 μm. Fig.3 shows calculated and measured transmission loss of the dielectric waveguide. Material parameters are assumed to be tanδ of 0.0005, εr of 2.3 for COP, and σ of 5.8×10^{7} S/m for copper. A designed 40GHz-band copper plated dielectric waveguide has been fabricated to measure transmission loss. The waveguide had the loss of about 0.1dB/cm over the frequency range between 43GHz and 48GHz. Good agreement is obtained between calculated data and measured data.

2.2 Four-way Divider/Combiner

The divider/combiner is composed of E-plane T-junctions and E-plane bends. A good match is achieved by optimizing matching elements in the T-junction. The designed four-way divider/combiner has been fabricated. Fig.4 shows a photograph of the fabricated divider/combiner. In this divider/combiner, common waveguide with the dimensions of 3.08×1.57mm, four branching waveguides with the dimensions of 3.08×1.13mm. Fig.5 shows measured and calculated return loss of the fabricated divider/combiner with a dielectric waveguide to hollow waveguide transformer. As shown in Fig.5, the fabricated divider/combiner has the VSWRs of less than 1.4 over the frequency range between 43GHz and 48GHz. Moreover, a good agreement is obtained between a calculated result and a measured result.

2.3 Grooved Waveguide Polarizer

Fig.6 shows the structure of a grooved waveguide polarizer [3]. The polarizer is composed of a circular waveguide with a groove. Because of the simple structure of the polarizer, it is possible to realize a circularly polarized array antenna by using injection molding. As shown in Fig.7, the polarizer has axial ratio of less than 0.5 dB in the frequency band of 42.6–47.3GHz (10.5% bandwidth).

Fig.8 shows the photograph of a fabricated grooved waveguide polarizer.Fig.9 shows the axial ratio of the calculated and measured characteristics and error analysis results. Transmission characteristics (amplitude and phase) of vertical and horizontal polarized waves are measured to evaluate the axial ratio of the polarizers. Manufacturing inaccuracy of the polariers is assumed to be +/-0.05mm. The fabricated polarizers have good performances, that is, the axial ratio less than 1.5 dB in the frequency band of 43.2–47.3GHz (9.1% bandwidth), and within variation of the error analysis. Note that the characteristics in these measurement results include two circular to rectangular dielectric waveguide transformers and two dielectric waveguide to hollow waveguide transformers.

3. Injection Molded Horn Array Antenna

As shown in Fig.1, the horn array antenna employing dielectric waveguide is composed of horn antennas, E-plane T-junctions, E-plane bends, and grooved waveguide polarizers. Low return loss of horn antennas are achieved by determining optimum length of dielectric rod from horn antenna aperture.

The designed dielectric horn array antenna has been fabricated. Fig.10 shows a photograph of the fabricated dielectric horn array antenna for the 40GHz band manufactured by injection molding process. This COP was made into a 16-element right-handed circularly polarized wave array antenna (16 x1). Fig.11 shows the return loss of the dielectric waveguide array antenna. As shown in Fig.11, the measured values almost agree with the calculated values. Good performances, that is, the VSWRs of less than 1.4, were obtained over the frequency band of 43–47.8GHz (bandwidth 10.5%). Note that the measurement result includes characteristics of the dielectric waveguide to hollow waveguide transformer. Fig.12 shows the results of the measured radiation pattern of the dielectric waveguide horn array antenna at 43.65 GHz. A measured gain of 19.4 dBi agree well with the calculated value (20.1[dBi]).

4. Conclusion

The dielectric waveguide horn array antenna, which is manufactured by injection molding, has been introduced. The mass production and cost reduction of millimeter wave-band antennas are enabled by the injection-molding technology. The fabricated injection molded horn array antenna has shown the technologies suits fore low-cost millimeter-wave applications.

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5. References

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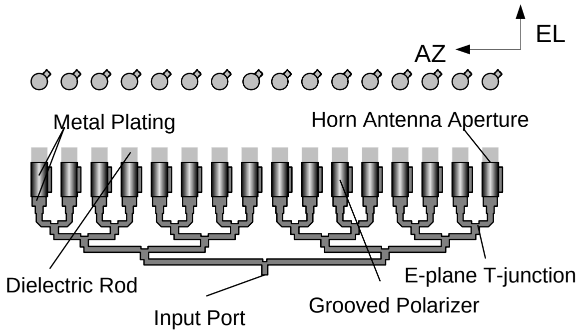

Fig.1. Structure of Waveguide Horn Array Antenna.

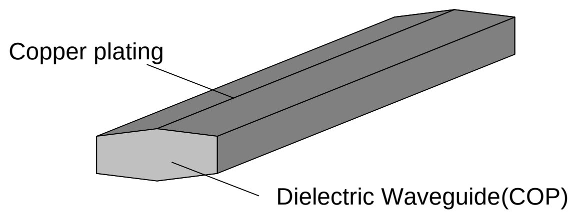

Fig.2. Structure of Copper Plated Dielectric Waveguide.

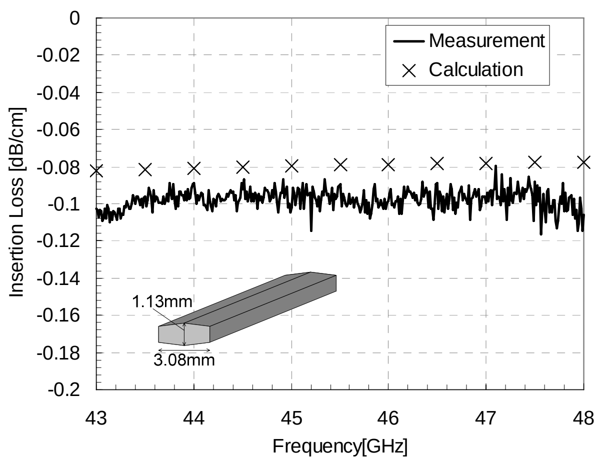

Fig.3. Measured and Calculated Transmission Loss of Fabricated Dielectric Waveguide.

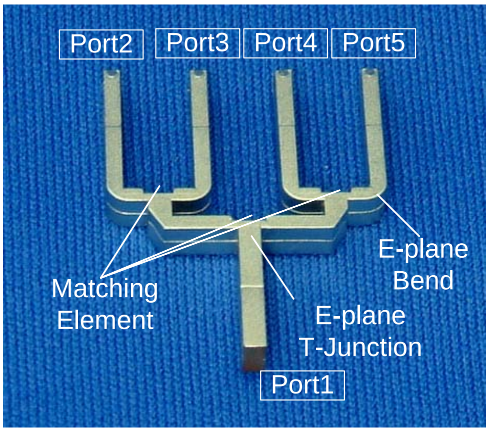

Fig.4. Photograph of Fabricated four-way Divider/ Combiner.

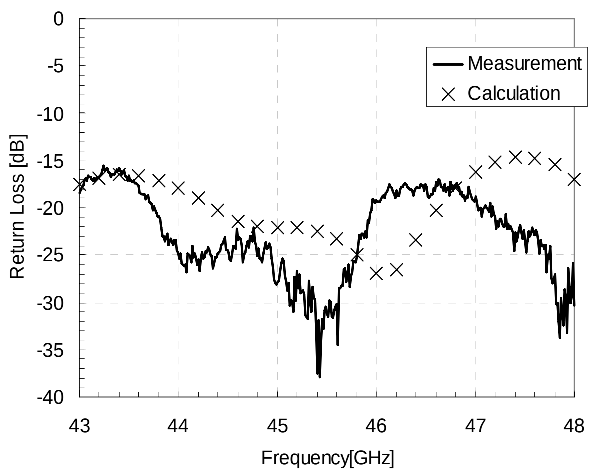

Fig.5. Measured and Calculated Return Losses of Fabricated four-way Divider/Combiner.

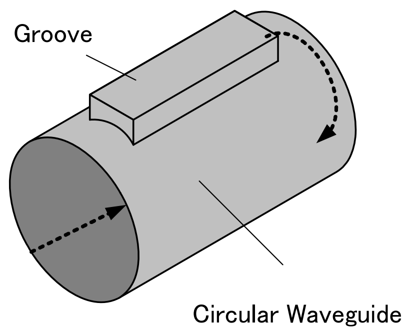

Fig.6. Structure of Grooved Waveguide Polarizer.

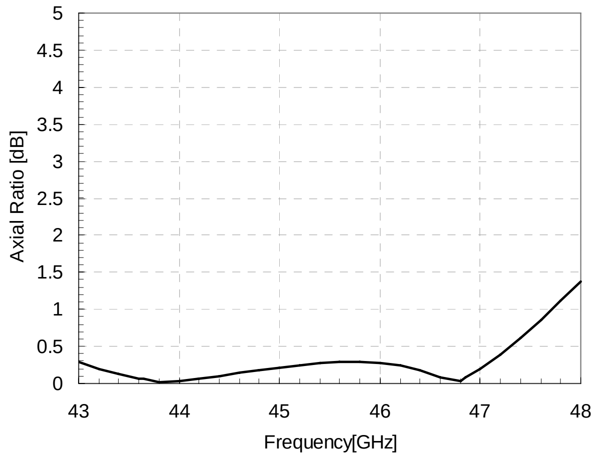

Fig.7. Calculated Axial Ratio of Designed Grooved Waveguide Polarizer.

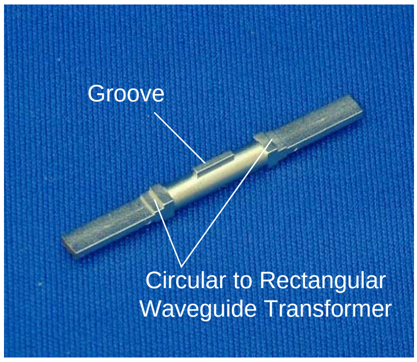

Fig.8. Photograph of Fabricated Grooved Waveguide Polarizer

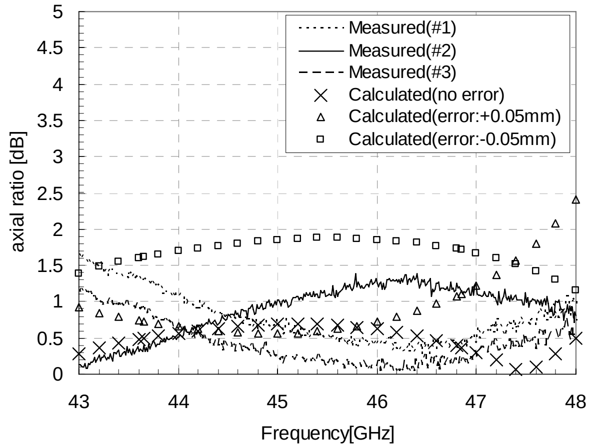

Fig.9. Measured and Calculated Axial Ratio of Fabricated Grooved Waveguide Polarizer.

Fig.10. Photograph of Fabricated Injection Molded Horn Array Antenna.

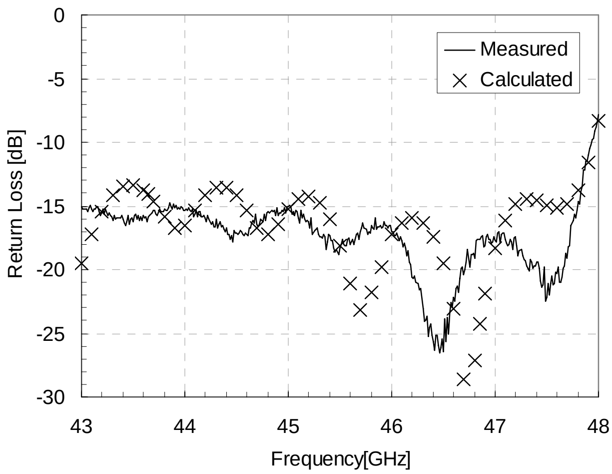

Fig.11. Measured and Calculated Return Losses of Fabricated Horn Array Antenna.

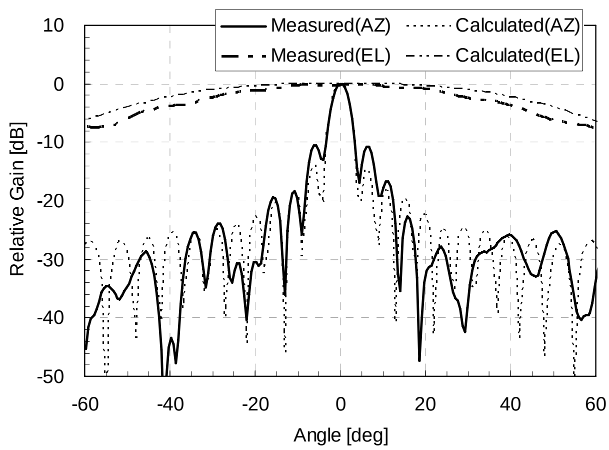

Fig.12. Measured and Calculated Radiation Patterns of Fabricated Horn Array Antenna at 43.65GHz.