Design of Microstrip-input Taper-structures for Required Beam Shape in Rotman-lens Phase Shifter

Yuta Suzuki, Kunio Sakakibara and Nobuyoshi Kikuma
Department of Electrical and Mechanical Engineering, Nagoya Institute of Technology
Gokiso-cho, Showa-ku, Nagoya, 466-8555, Japan
E-mail: sakaki@nitech.ac.jp

Abstract **- Rotman-lens is widely used in multi-beam antennas for beam forming networks which give required beam directions. Discrete beam-scanning can be fulfilled by switching beams. However, a part of the radiated power from the input port to the Rotman-lens which delivers outside of the output port arrangement becomes loss to the dummy ports. Therefore, optimizing the connection angle and the tapered width of the input port, the transmission efficiency is expected to be improved. The structure of the input port arrangement is optimized in this work. The effect for the efficiency improvement is demonstrated in this paper.**

Index Terms **— Rotman-lens, beam-switching, feeding circuit, microstrip antenna, millimeter wave**

1. Introduction

High-speed wireless communication systems [1], [2] and automotive radar systems [3]-[5] using millimeter waves have been developed in recent years. Multi-beam antennas covering a wide area with high gain have attracted attention. A Rotman-lens phase shifter [6] is a feeding circuit which divides input power with required phase distribution to the array elements. Rotman-lens performs over wide frequency bandwidth because of the lens nature. Low profile is also an attractive property from the planar structure composed of the parallel plate transmission line in the printed substrate. However, a part of the radiated power from the input port to the Rotman-lens which delivers outside of the output port arrangement becomes loss to the dummy ports. Furthermore, the deviation of the uniformity on the aperture causes degradation of aperture efficiency.

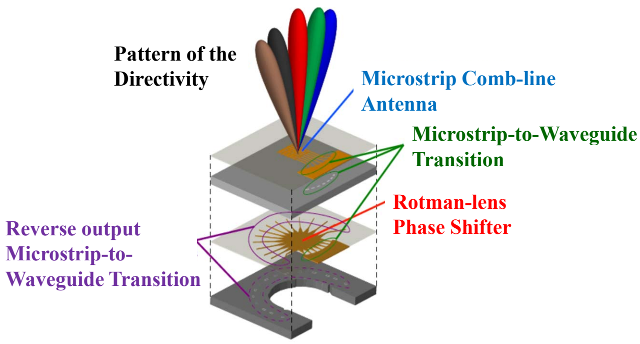


Fig. 1. The layered antenna module using Rotman-lens phase shifter.

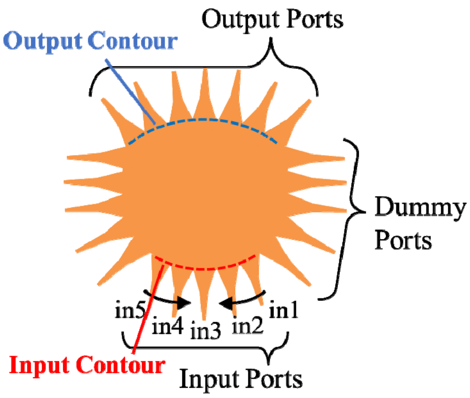


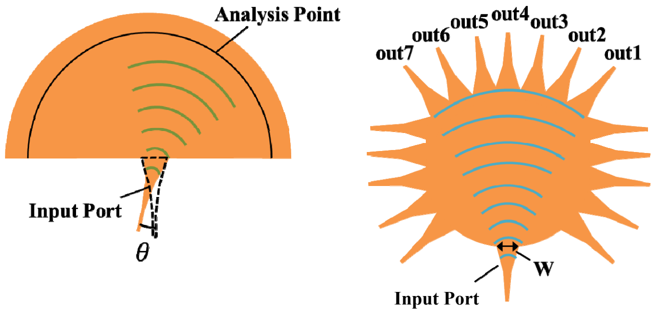
Fig. 2. Rotman-lens phase shifter.

Rotman-lens feeding circuit is fed by taper structures from microstrip lines. The connection angle and the angler width of the input tapers are designed to fit the radiation angle to the output port arrangement in this work. Low loss to the dummy port and high efficiency are expected. The principle and the optimization design of the Rotman-lens phase shifter are shown in Sec. 2. The simulated characteristics of the Rotman-lens phase shifter using the optimized input ports are shown in Sec. 3. Finally, this paper is concluded in Sec. 4.

2. Principle and Optimization Design of Rotman-lens Phase Shifter

(1) Principle

A layered antenna module fed by a Rotman-lens phase shifter is shown in Fig. 1. The microstrip comb-line antennas [7] are fed by the backed Rotman-lens phase shifter through the microstrip-to-waveguide transitions [8]. The power fed from one of the input ports transmits through the Rotman-lens to all output ports shown in Fig. 2. The inclination angle of the phase distribution over the output ports are different depending on the input ports, which results in array feeding for different beam directions. Rotman lens performs as a multiple-beam feeding circuit. The developed Rotman-lens phase shifter is fed by



(a) semi-circular model (b) Rotman-lens model

Fig. 3. Analysis models.

microstrip lines and is composed of a planar lens with tapered connections from input, output and dummy ports. The lens contour is designed as the path lengths from the center input port to all output ports are equal. The tapered connection is formed so that no gap between adjacent tapered connections over the lens contours. Arranging dummy ports between the input and output contours at the both sides of the lens prevents two-dimensional standing wave in the lens due to the reflections from the lens end.

(2) Optimization of Input Ports

The conventional input port is connected to the lens contour perpendicularly. To reduce the power to the dummy port, the angles and widths of the input port are optimized. First, the semi-circular analysis model for optimization of the angle is shown in Fig. 3(a). The connection angle θ was optimized to 14.0 and 6.0 degrees for input ports in1 and in2, respectively, so as the center of the −10 dB beamwidth directs the center of the output contour. Then, the tapered widths W of the input ports are optimized to 2.78 mm using the Rotman-lens model shown in Fig. 3(b), so as uniform distribution to all the output ports is obtained.

3. Simulated Performance of Rotman Lens

(1) Transmission Characteristics

The effect of the optimization in the input tapered structures is evaluated by electromagnetic simulation of the finite element method. The transmission characteristics of the Rotman-lens phase shifters are shown in Fig. 4. A large deviation was observed in the transmissions to the output ports for the conventional connections. However, the transmissions to the output ports for the designed connections were improved to be uniform distribution.

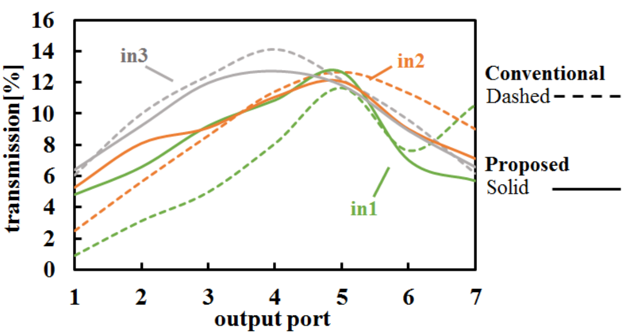


Fig. 4. Transmission characteristics.

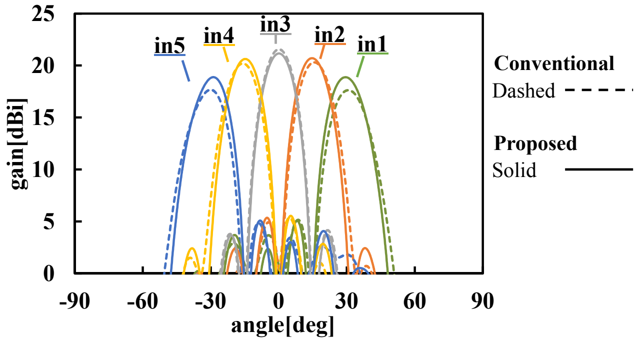


Fig. 5. Antenna realized gains.

(2) Radiation Patterns and Gains

One-dimensional microstrip antennas are connected to the output ports of the Rotman-lens phase shifters. The simulated radiation patterns and gains of the proposed model were compared with the conventional model as is shown in Fig. 5. The gain of the proposed model fed from the center port in3 decreased from the conventional model by 0.4 dB. When the power is input from the ports in1 and in5, the gain increased by 1.2 dB. When the power is input from the ports in2 and in4, gain increased by 0.4 dB. Consequently, it is confirmed that the uniformity of all five beams are improved.

4. Conclusion

The tapered structures of the input ports for the Rotman-lens phase shifter are optimized in this paper. When the power inputs from the ports in1 and in2, the gain is increased by 1.2 dB and 0.4 dB respectively. The effect of the proposed structure was confirmed.

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