Multiple Beam Antenna Arrays for Indoor Communications

Yuming Tao, étudiant 3^e^ cycle

Dr Gilles Y. Delisle, directeur de recherche

Abstract: A practical design of a compact integrated Rotman lens is presented, which will be used as a beamforming of multiple beam antenna array in millimeter wave band personal communication systems. A conventional microstrip patch array, fed by designed Rotman lens, is designed and tested. Some simulation and experiment results are also presented.

Résumé: Une conception pratique d'une lentille Rotman intégrée est présenté. Elle sera utilisée pour créer un faisceau d'une antenne réseau dans la bande millimétrique des systèmes de communication individuel. Une antenne réseau microruban, alimentée par une lentille Rotman, est conçue et testée. Des résultats de simulation et expérimentales seront aussi présentés.

I. Design of Multiple Beam Antenna Array

One microstrip patch array fed by a integrated Rotman lens has been designed and tested to estimate the beamforming performance of designed Rotman lens in millimeter wave band. The design of Rotman lens' contour has been presented in our previous reports and references [1], therefore we only talk about the rest of antenna design, such as microstrip taper, patch array, the transmission line between the array ports and the array, and the reduction of multiple reflection inside lens cavity as well.

First, the following specifications are initially taken into account: frequency range of 27 ~30 GHz, certain number of beams covering 100˚~120˚ angular sector, around -3 dB adjacent beam crossover levels. From these, 11 array elements with spacing $d = 0.56\lambda_{min}$ may be inferred to provide half-power beamwidth of 10˚ to 15˚ depending on beam scanning angle without appearance of grating lobe, and λ_{min} is the minimum wavelength related to the highest operating frequency.

Then, several types of microstrip tapered transition between array port and the 50Ω microstrip line are investigated but the linear taper is adopted in our design. The angle of a linear taper affects the overall dimension of lens and impedance matching between microstrip line and low-impedance array port. After several trials, it has been concluded that a linear microstrip transition with flared angle from 12° to 15° is a reasonable choice for practical microstrip lens design[2].

The 50Ω microstrip lines should be designed carefully, which could cause phase distribution errors in array elements. The lengths of these lines are unequal due to (a) the Rotman lens '*w*' differential, and (b) the variation in effective electrical length of the array ports due to their different pointing deflection angles, which results in different port shapes.

Fig. 1 Shows the layout of multiple beam antenna fed by Rotman lens. Each beam or array port has to be flared from a thin 50Ω line to a certain width of lens output aperture and each array port connected to the array element via a transmission line with specified length.

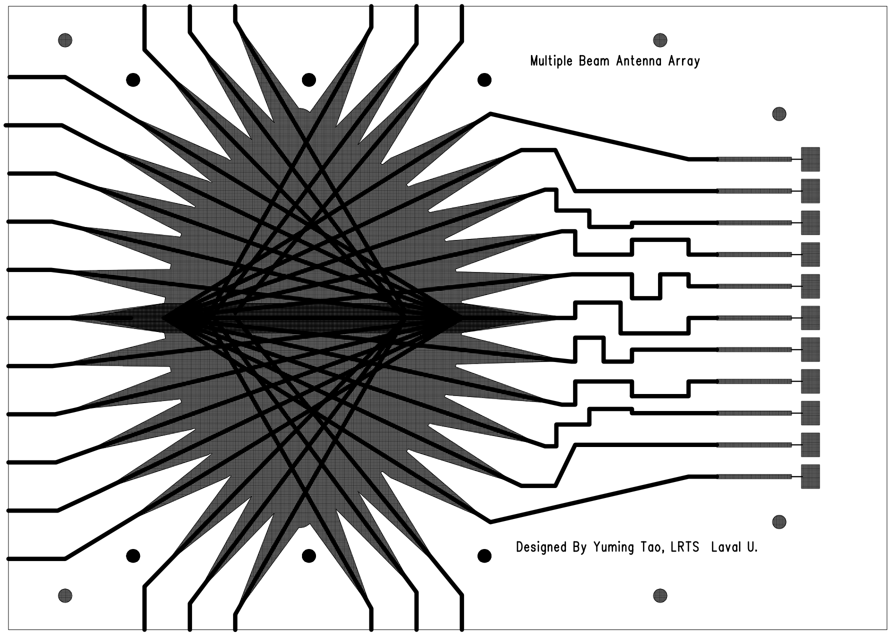

Fig. 1 Multiple beam antenna fed by Rotman lens

II. Experimental Results

To estimate the performance of the designed Rotman lens, a multiple beam antenna array formed by a microstrip patch array and lens has been designed, fabricated and tested. The multiple beam radiation patterns are measured and plotted in Fig. 2. The beam pointing direction could be stirred among the angular range of 90° ~ 100° as the input port changed. The half-power beamwidth of each beam varies among the angle of 9° to 12°, gain from 5.5 dB to 10.5 dB, and side lobe level below -9 dB or -10 dB. The details are given in the Table 1.

The experimental results also indicate that it is difficult for the maximum scanning angular range to reach up to 120° with Rotman lens but 90° or 100° quite possible. The total losses seem to be higher than the expected, which may result from lots of factors, mismatching, multiple reflection inside lens cavity, the attenuation of microstrip lines and connectors. Further, this causes the gain of the whole antenna decreased.

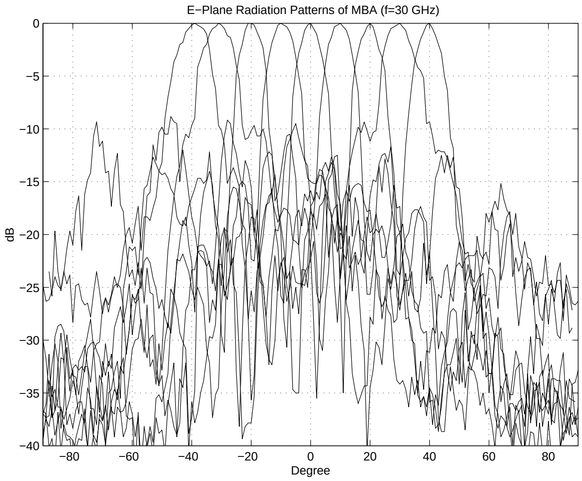

Fig. 2 Radiation patterns of multiple beam antenna at 30 GHz

TABLE 1. The performance of MBA antenna shown in Fig. 1 at 30 GHz

Beam port	I_1 (40˚ beam)	I_2 (30˚ beam)	I_3 (20˚ beam)	I_4 (10˚ beam)	I_5 (0˚ beam)
Beamwidth	12.0˚	11.0˚	10.0˚	10.0˚	9.0˚
Gain*	5.5 dB	8.17 dB	8.67 dB	10.67 dB	10.5 dB

*** The Gain is referred to the simulation result of a single patch antenna at 30 GHz.**

III. Future Work

Future work will be focused on the modification of Rotman lens, wide band array antenna design and final integration of overall multiple beam antenna.

References:

[1] Y. M. Tao and G. Y. Delisle, “Design of Compact Integrated Rotman Lens for Multiple Beam Array”, Digest of ISAE’97, Xi’an, China, August 22-26, 1997.

[2] L. Musa and M. S. Smith, “Microstrip Port Design and Sidewall Absorption for Printed Rotman Lenses”, IEE Proceedings, Vol. 136, Pt. H, No. 1, pp. 53-58, Feb. 1989.