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94GHz Monopulse Folded Reflectarray Antenna

#Hanseung Lee[1], Heeduck Chae[1], Jonghoon Chun[2] and Sangwook Nam[1]
[1]School of Electrical Engineering and INMC, Seoul National University
Seoul, Korea, seung346@ael.snu.ac.kr
[2] SamsungThales R&D Team
Seoul, Korea, jonghoon.chun@samsung.com

1. Introduction

Various forms of automatic precision tracking have been developed that are based either on sequential or on simultaneous lobing. The concept of monopulse emerged from simultaneous lobing. In either case the angle of arrival of the incoming wave is determined by comparing the signal received on two or more non-coincident antenna patterns. This is the physical basis of most target-tracking techniques and the comparison is made simultaneously in a monopulse radar systems [1]. Compact, low profile millimetre wave monopulse antennas have many applications in automatic tracking radars and precision RF sensors. The folded reflectarray antennas using reflectarray and polarizing grid offer a low cost, low loss and low profile alternative to parabolic reflector antennas [2]. Therefore a monopulse antenna consisted of folded reflectarray satisfies recent demands of monopulse radars. In this paper, we show configurations of a reflectarray and a polarizing grid designed at a center frequency of 94GHz along with the measured results. Also designs of a comparator which is an essential device to compare received signals and a multi-mode feed horn are given, and show performances of these devices.

2. Designs of Reflectarray and Polarizing Grid

A reflectarray must do beam forming and polarization twisting. So the reflectarray element need at least 2-degree freedom. Thus patch of variable size is suitable for reflectarray element. The basic design principle is that the phase φ_i of the field reflected from an element in the reflectarray be chosen so the total phase delay from the feed to a fixed aperture plane in front of the reflectarray is constant for all elements. The patch axes are tilted by 45° with respect to the incident E-field. And the field can be decomposed into components parallel to the two axes of the dipoles. So if a phase difference between the two components of the reflected wave is π, the polarization of reflected wave tilted by 90° with respect to that of incident one. The phase delay φ_i can be obtained by numerical method [3-5]. In this paper, Spectral domain moment method with Eward summation and Floquet mode theorem [4] is used. Fig. 1 show the layout of a reflectarray designed at 94GHz and its fabricated picture.

Polarizing grid is the polarization selective surface. It is realized using slot array. A fabricated polarizing grid designed at a center frequency of 94GHz and simulated scattering parameters are shown in Figure 2.

3. Waveguide Comparator Using Circular Cavity Hybrid [6]

In a monopulse radar system, a comparator is an essential element to compare received signals. The general monopulse comparator arithmetic network is shown in Figure 3. With four signals from four horn ports (Ⅰ, Ⅱ, Ⅲ, and Ⅳ), the sum channel signals are derived in the following manner: (1) Positive reference signals Ⅰ and Ⅲ are combined in phase in the upper section of the hybrid junction. (2) Positive reference signals Ⅱ and Ⅳ are combined in phase in the lower section. (3) These signal pairs (Ⅰ + Ⅲ) and (Ⅱ + Ⅳ) are then combined in phase to form the sum channel signal. The difference channel signals arise by anti-phase addition of the appropriate

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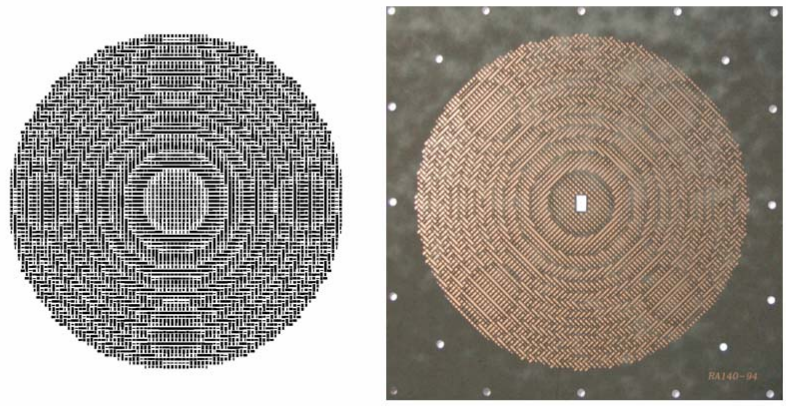

Fig. 1. Reflectarray layout (left) and picture (right)

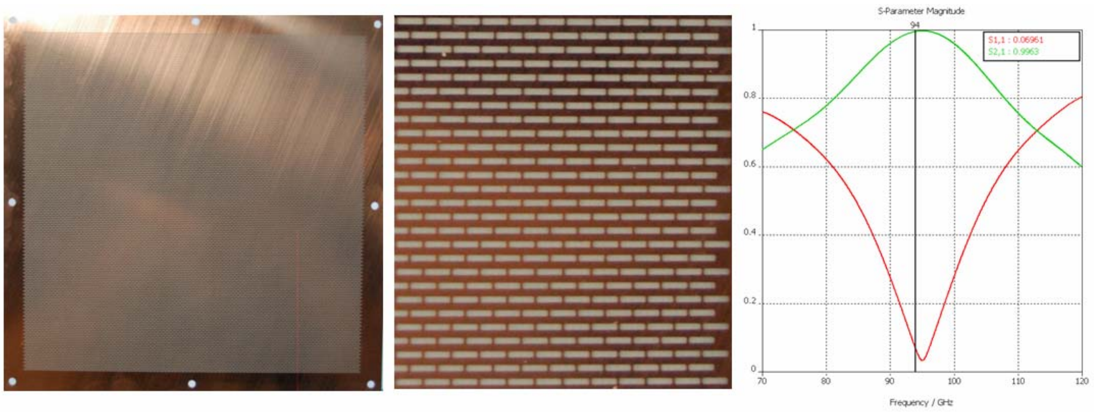

Fig. 2. Photograph of fabricated polarizing grid and its S-parameter

pairs of signals: (Ⅰ + Ⅲ) - (Ⅱ + Ⅳ) provides the elevation difference; the azimuth difference is provided by (Ⅰ + Ⅱ) - (Ⅲ + Ⅳ).

Fig. 4 shows a fabricated comparator designed at a center frequency of 94GHz. This comparator circuit is machined from small split blocks of metal that are 80 millimeters in diameter and 15 millimeters thick (8cm×1.5cm). A computerized milling machine is used to obtain very fine control of the machining tolerances. Positioning accuracy of worst cases of the machine is 0.05mm on each of three axes and the largest fabrication error is 0.1mm. As a result, we should have designed a comparator layout considering length errors. Fig. 5 exhibits the magnitude of all scattering parameters of the comparator. In the above results, the comparator shows a wide bandwidth. With four signals from four horn ports, each signal is divided into four output ports. In other words, the signal power from the output port is less four times than input power. For this reason, S-parameters for passing through the comparator are -6dB. Fig. 6 show the phase of scattering parameters of the comparator for all output port. From these results, port 5 generates the azimuth difference channel signal, port 6 generates the sum channel signal, and port 8 generates the elevation channel signal.

4. Multimode Feed Horn

In 1961, PW Hannan presented design objectives for optimum antenna feed systems for reflector type antennas in monopulse applications. The implementation of these ideas were found to be best achieved with multimode antenna feeds where, typically, a number of waveguide feeds are first combined into one overmoded waveguide, which terminates in the radiating aperture [7]. By exciting the four input waveguides in three different ways, three antenna patterns, called sum, azimuth, and elevation channels, are obtained. The resulting structure and simulated far fields are shown in Fig. 7.

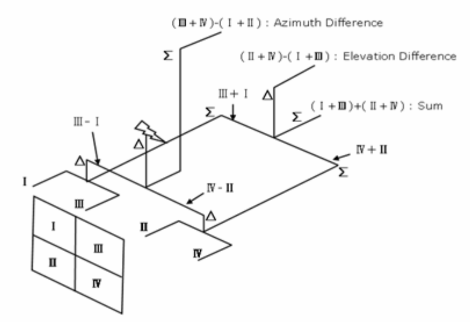

Fig. 3. Comparator block diagram

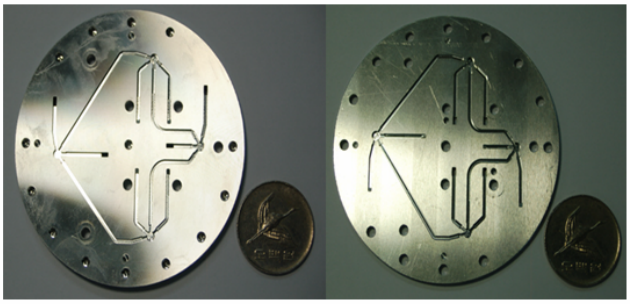

Fig. 4. Photograph of fabricated comparator

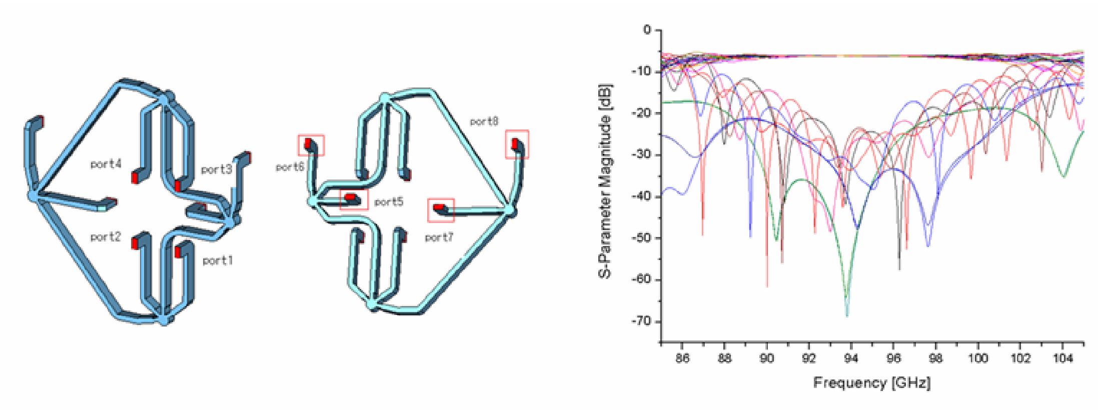

Fig. 5. Layout and S-parameters (magnitude) of comparator

5. Antenna Performance

We made the reflectarray using 0.254mm thick RT-Duroid-5880 substrate fixed by an aluminum plate. The polarizing grid was made by 3.38mm thick RO-4003 substrate. Fig. 8 show a total antenna system and a measurement setting. Measured maximum gain of the 94GHz monopulse folded reflectarray antenna is 35dBi. In order to know specific characteristics of the antenna, radiation patterns will be measured.

6. Conclusion

A 94GHz monopulse folded reflectarray antenna has been designed and high antenna gain has been realized. The suggested antenna is marked by its easy manufacture and small depth. Since the monopulse comparator is made by a waveguide, the antenna also endures to high-power. Therefore we can expect application at W-band monopulse radar systems where require a miniature size and a durability for high-power.

Acknowledgments

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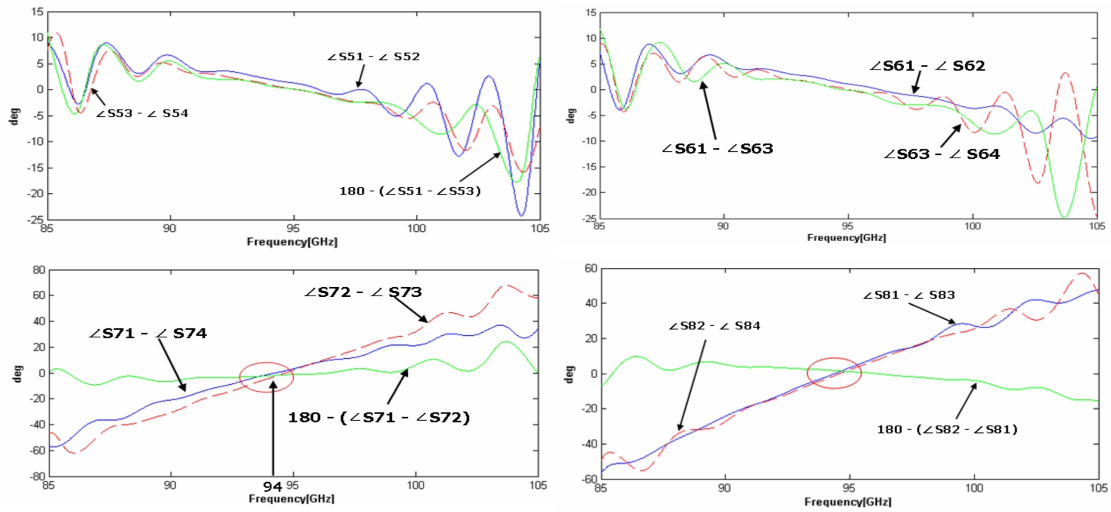

Fig. 6. S-parameters (phase) of comparator

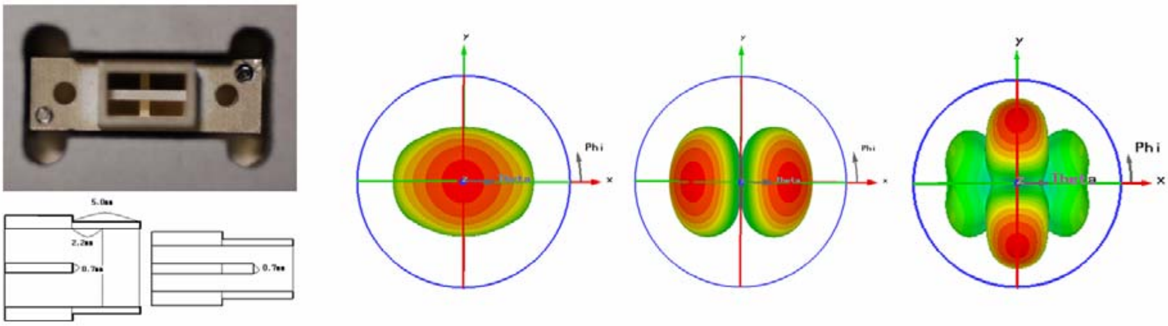

Fig. 7. Multimode feed structure (left) and its far field (right)

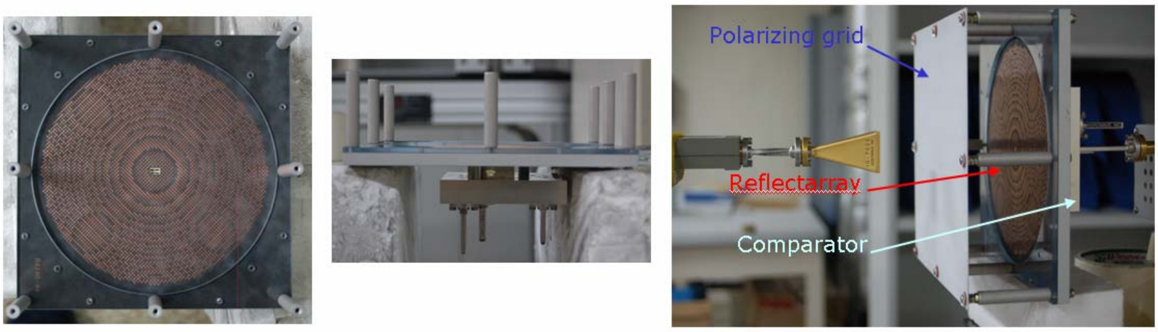

Fig. 8. Pictures of the folded reflectarray antenna and a measurement setting

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