Microwave Circular Polarization Plane Array Antenna with Wideband Axial Ratio and Supressed Horizontal Power Radiation

YUMI TAKIZAWA† and ATSUSHI FUKASAWA††

†Institute of Statistical Mathematics
Research Organization of Information and Systems
10-3 Midori-cho, Tachikawa, Tokyo, JAPAN
takizawa@ism.ac.jp

††Technical Adviser, Musasino Co. Ltd.
Former Professor, Chiba University
Kamimeguro, Meguro-ku, Tokyo, JAPAN
fukasawafuji@yahoo.co.jp

Abstract: - This paper presents a microwave circular polarization plane antenna. Plane antenna provides a compact antenna, but the circular polarization roundness was not enough and narrow band. S-type routing wires and grounded collar are newly given in this paper. The former provides circuits minimizing reflection points in routing wires which contributes perfect roundness in wideband. The latter eliminates power in horizontal plane and enhances the power along vertical axis. High performance 64-antenna array was presented in this paper. Almost perfect roundness (axial ratio less than 3dB) was realized by reducing power reflections in routing wires. And directive gain 24dB, which is 3 dB enhanced by the grounded square collar, are obtained. The number of antennas 64 in an array was reduced into a half or less of conventional number 128.

Key-Words: - Circular polarization plane antenna, horizontal radiation, S-type routing wire, Grounded square collar.

1 Introduction

Circular polarization microwave plane antennas will be expected in wide area of remote sensing systems [1,2]. Microstripline plane antennas are popular to compose circular polarization antennas.

The circular polarization gain-bandwidth of a single or multiple-antenna array are not wide enough to cover expected all bandwidth, 10 per cent of central frequency in X-band as an example. But the bandwidth is less than 2 per cent or so.

The authors have studied schemes and possible structures of circular polarization antennas and arrays for high values of gain and bandwidth [3-11].

In this paper, novel technologies of S-type routing wires and grounded collar are presented. The former provides circuits to minimize reflection from multiple points in routing wires, which contributes perfect roundness of circular polarization. The latter enhances vertical gain, and reduces radiation in horizontal plane.

2 Single Antenna

2.1 Single antenna composed of triplate stripline resonator

The proposed antenna is made on a three-layered substrate. Microwave resonator is made of a feed element (***a***), a reactance element (***b***), and ground plate (***g***) between dielectric substrates 1 and 2.

The feed element ***a*** is given by a circular disc with truncation at both diagonal sides.
The reactance element ***b*** is given by a circular disc. It provides additional capacitive or inductive components for resonance.

In Fig. 1, the diameters of feed- (***a***), reactance-elements (***b***), and ground plate (***g***) are $2r_a$, $2r_b$, and $2r_g$ respectively. ag is the width of circular folded ground connected to the lower ground plate ***g*** of the stripline. The distances between ***g***, ***a***, and ***b*** and are d_a and d_b. The routing wires for feeding is formed on the surface of the substrate under the ground.

2.2 Electric operation

The resonance of each unit antenna is composed of main element ***a***, reactance element ***b***, and ground plate ***g*** as shown in Fig. 1. ***b*** is a round disc truncated lineally at the both sides as shown in Fig. 2. Two resonance modes are given by ***a*** along *x* and *y* axes.

Reactance element ***b*** works as a reactive tuning of resonance, and simultaneously as a transmitter of microwave along *z* axis.

In this structure, three resonant frequencies appear at f_L and f_H by the element *a*, and f_M by the element *b*, where the relation is kept as ;

$$f_L < f_M < f_H \tag{1}$$

In this structure, the current i_L (f_L) is delayed and i_H (f_H) is proceeded by magnetic and electric coupling between current i_M (f_M) on the element ***b***.

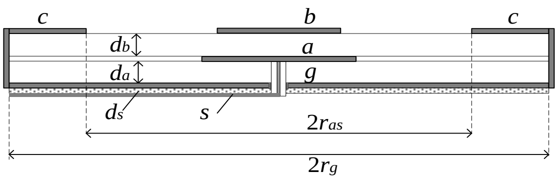

Fig.1 Cross setional view of the proposed antenna.
a : feed element, *b*: reactance element,
g : ground plate, *c* : grounded collar.

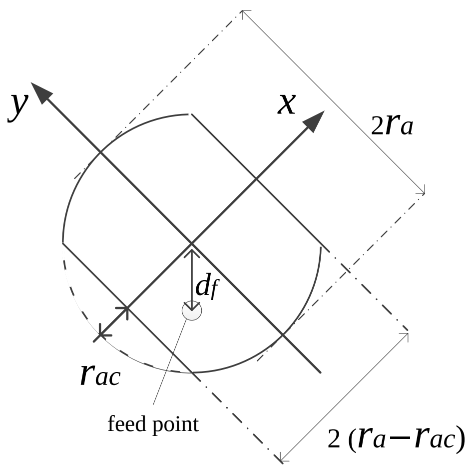

Fig. 2 Main element *a* with feeding.
df: Feeding point.

Circular polarization is realized by the time-space vectors i_L and i_H being controlled by the vector i_M ,

It is pointed that another scheme was given by M. Haneishi, et al [1]. Circular polarization was realized by a rectangle slot in the center of the circular feeding element.

3 Four-Antenna Array

3.1 Configuration of 4 antenna array

Four-antenna array is composed by orthogonal arrangement. Microwave power is fed by smoothed routing wires shown in Fig. 3. Four antennas a_i, (i = 1~4) are set at each quadrant around the center *O* in *X* – *Y* plane. *Z* axis is perpendicular against *X*-*Y* plane.

Each antenna generates right-handed polarized wave. To get right-handed polarized wave totally, each antenna must be fed by the signal with 90 degree phase delay along the direction left-handed circulation. d_f shows the position of feeding point at each antenna.

The diameter of the ground plate 2*rg* must be large enough compared to the size of total space of inner conductors.

3.2 Routing wire for feeding

The design of routing wires for feeding to four antennas is shown in Fig. 3. This scheme forms a parallel composition of routing wire.

The condition of 90 degree phase difference are given between right hand elements *a*1 vs *a*4, and the left hand elements *a*3 vs *a*2. At the connection of the right and the left elements, 180 degree and 90 degree phase delay are provided by corresponding line lengths.

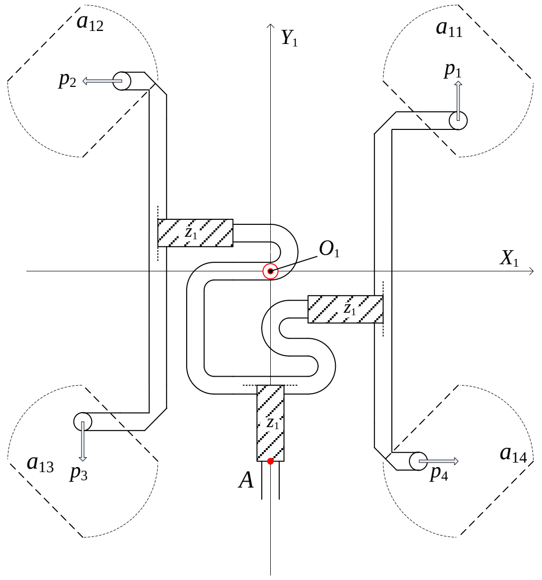

Fig. 3 Smoothed routing wire for a 4-antenna a_{11} ~ a_{14}, and p_1 ~ p_4 are feeding Poynting vectors at the first quadrant. O is the centre of the plane X_1-Y_1. A is the input point of feeding. z_1 and z_0 are characteristics impedances of routing wires.

4 16-Antenna Array

4.1 Spatial arrangement

The Cartesian system x- y – z is used in Fig. 4. The z axis is vertical to the page and frontward.

An array antenna system is set on x – y plane, and microwave radiates along z axis.

The points A, B, C, D stand the input ports of each four-antenna array.

The direction of each four-antenna array turns right on x – y plane.

The phase of each local array proceeds 90 degree along right hand rotation.

Here, phases of fed signals at the points A, B, C, D are delayed 90 degree.

By the above operations, the phase differences are cancelled, and it provides synchronized circular polarization waves.

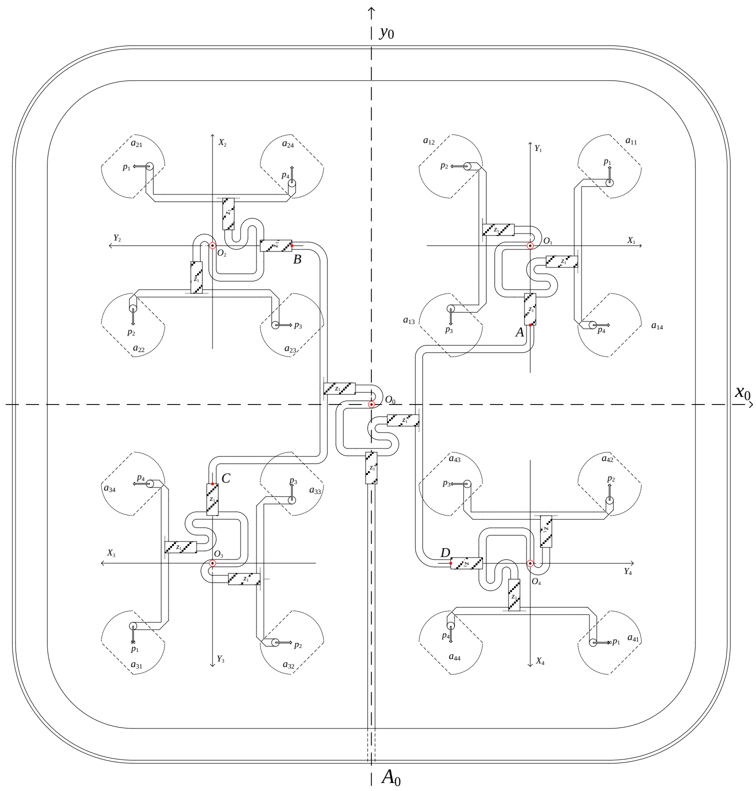

Fig. 4 Circular polarization array antenna with 16 antennas and grounded square collar.
The 4-antenna array is allocated in each quadrant with right hand turning 90 degrees.
Microwave input port is shown as A_0.

4.2 Elimination of cross-sectional radiation

A square collar is shown at the peripheral of the array in Fig. 4. This collar forms a quarter wavelength line with short termination. Cross-sectional microwave radiation is eliminated. This collar is set to match the impedance of cross-sectional radiation. This is connected to the stripline ground plate.

5 64-Antenna Array

5.1 Spatial arrangement

64-antenna array is composed of 16-antenna array, which are arrange at each of four quadrants. The Cartesian system *x*- *y* – *z* is used. The *z* axis is vertical to the page and frontward.

This array is composed on *x* – *y* plane, and microwave radiates along *z* axis. The top view of 64-antenna array and routing wire for feeding are shown with grounded collar in Fig. 5.

The direction of each 16-antenna array turns right on *X* – *Y* plane. The phase of each local array proceeds 90 degree along right hand rotation. By the above operations, the phase differences are cancelled, and it provides synchronized circular polarization waves.

5.2 Grounded square collar

The peripheral of the array is covered by a square collar as shown in Fig. 5. This collar composes a quarter wavelength line with short termination. Cross-sectional microwave radiation is eliminated by this collar. This collar is designed to match the impedance of cross-sectional radiation from inside the array. This is connected to the stripline ground plate. It is pointed that elimination of cross-sectional radiation energy contributes to increase forward radiation energy. Finally it provides enhancement of forward directive gain.

This scheme to reduce horizontal microwave power radiation has not been proposed yet in conventional theoretical study and development.

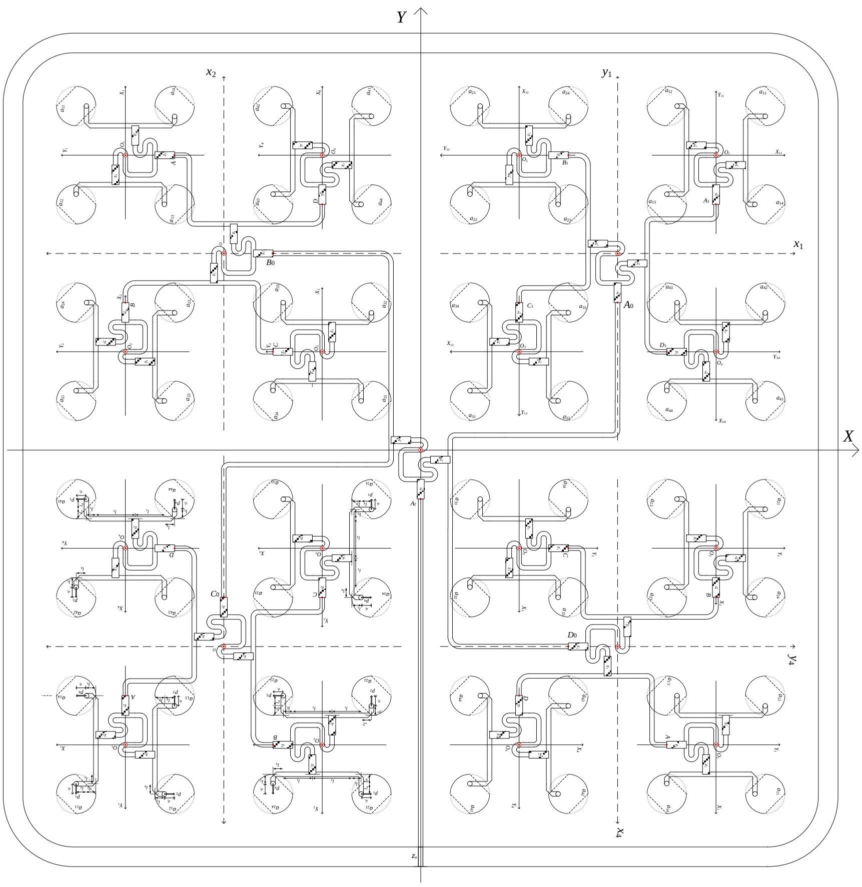

Fig. 5 Top view of 64- antenna array and feeding routing wire with grounded square collar.
The 16-antenna array is allocated in each quadrant with right hand turning 90 degrees.

6 Characteristics of the Proposed 64-Antenna Array

6.1 Parameter values

The central frequency and the bandwidth are designed for the X-band.

Thickness of the substrate; da = 1.6 (mm), db = 1.6 (mm), ds = 0.38 (mm). Permittivity ε_r is 2.17.

The length of the resonator is 10.0 (mm) for lower frequency length, and 7.0 (mm) for high frequency resonator. The diameter of reactance element is 8.0 (mm).

Each of 4-antenna arrays is orthogonal with each other along x and y axes.

The spacing d between antennas are chosen by experimentally depending on center frequency and expected bandwidth.

6.2 Characteristics and evaluation

Frequency characteristics of the proposed array antenna are shown in Fig. 6 ~ 10. 3D computer simulation was done using the software of CST Studio Suite.

(1) Return loss

The frequency characteristics of return loss is shown in Fig. 6. The bandwidth of return loss 10 (dB) is 2 (GHz) or more.

(2) Directive gain

The frequency characteristics of directive gain is obtained. The maximum gain was 24 (dB) or more.

(3) Input impedance

The frequency characteristics of input impedance is shown in Fig. 7. The source impedance is 50 (Ω). The upper and the below curves are the real and the imaginary parts of complex impedance.

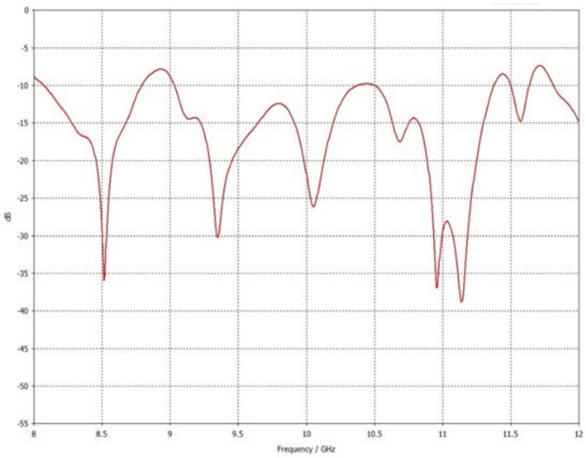

Fig. 6 Return loss (dB).

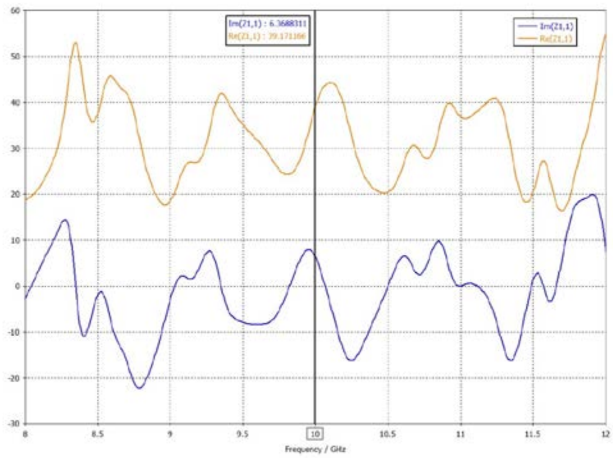

Fig. 7 Input impedance (Ω).
upper lines : real part
lower lines: imaginal part

(4) Axial ratio

The frequency characteristics of axial ratio is shown in Fig. 8. The axial ratio of circular polarization is smaller than 1.5 (dB) between 8.5 ~ 12 (GHz). The axial ratio shows small and wideband characteristics of circular polarization at X band.

(5) Farfield directive gain

The far field directive gain is given by polar scale in Fig. 9 and 10. The side lobe level was −12.8 (dB) from the main lobe. It means sharp beam of radiation was given. It was found that the directive gain of this array was 24 (dB) which is 2.5 (dB) approximately better than the gain without the grounded square collar.

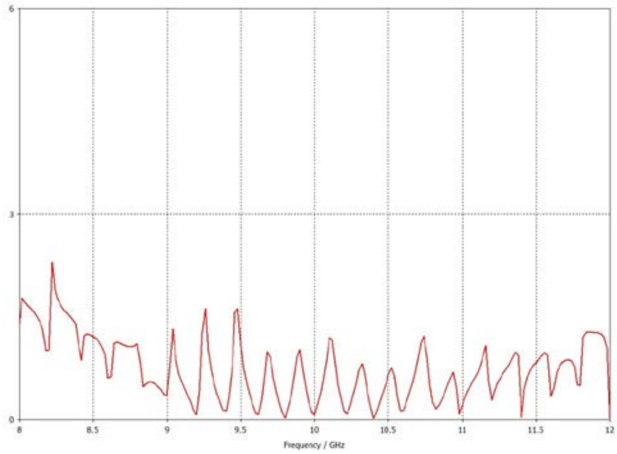

Fig. 8 Axial ratio (dB).

7 Conclusion

A novel configurations was presented with the S-type routing wires and the grounded square collar. The former provided less reflection to realize almost zero dB in circular polarization roundness and wideband width of axial ratio. The latter provided to reduce horizontal power radiation and to enhance the vertical directional gain.

The compact size and high performance were realized in 64-antenna array.
In this paper, the number of antenna 64 was found half or less of conventional array with 128 or more to meet the equal specific conditions. Furthermore, almost perfect roundness was realized by reducing power reflections in routing wires. And directive gain 3dB and effective reduced horizontal radiation were obtained against conventional design without grounded collar.

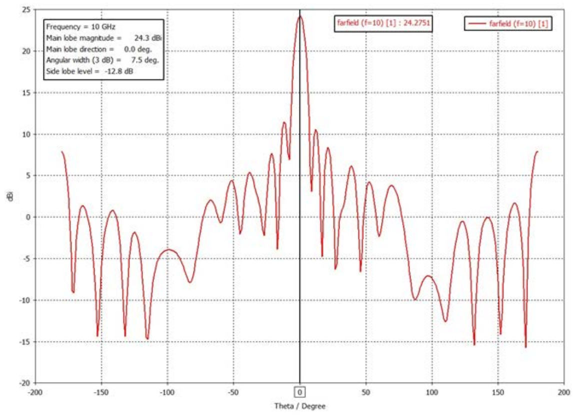

Fig. 9 Farfield directivity (dBi). φ = 0°.

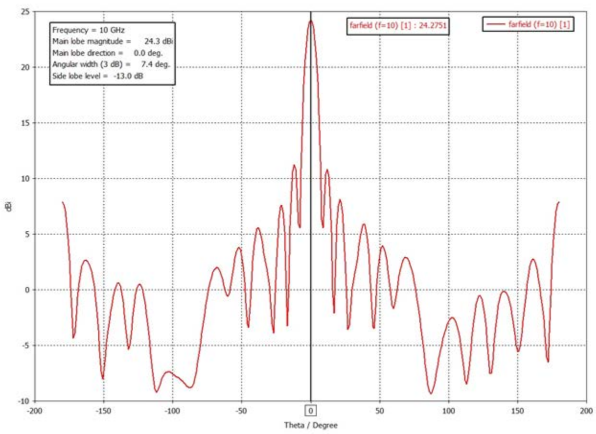

Fig. 10 Farfield directivity (dBi). φ = 90°.

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