Circular Polarization Plane Antenna Array by Anti-Parallel Arrangement with Simplified Routing Wires

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Abstract: -This paper presents a novel configuration of circular polarization array antenna. First in this paper, a structure of a single plane antenna is given. This antenna is composed of three elements of feed and reactance elements, and ground plate. Then, the required condition of phases in space and time is given. Novel configuration of 4-antenna array and routing wires are given to satisfy the condition. The novel scheme of this routing wire is simple and never known before. The characteristics of the proposed antenna array are obtained by 3D computer simulation. It was found that this scheme is applicable to wideband and practical systems.

Key-Words: - Circular polarization, plane array antenna, parallel feeding, anti-parallel arrangement, simplified routing wire.

1 Introduction

Recently circular polarization microwave antennas are studied and utilized in remote sensing and control of environmental applications.

Novel technologies have been studied by the authors;
(1) A novel resonators of degenerated resonators for circular polarization antenna was first given using circular disk with linear truncation at both diagonal sides.
(2) Orthogonal arrangement for array with four antennas were given for wideband axial ratio and high gain.
(3) Novel design of routing wire for feeding was given by smoothed lines (-S-type) in place of rapid bending lines (T-type).
(4) Novel design of structures of distributing antennas on a plane of array antenna was given in this paper. A microwave eliminator was provided to the peripheral of stripline antennas.
(5) Novel scheme of simplified configuration of microwave routing wire for feeding to 4 antenna array is presented in this paper.

2 A Single Plane Antenna

2.1 Configuration of the proposed single antenna

The proposed antenna is made on a three-layered substrate as shown in Fig.1. 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 as shown in Fig. 2. It provides half wavelength resonator with duplicate modes formed by truncation.

The reactance element ***b*** is given by a circular disc as shown in Fig. 1 and 3. It provides additional capacitive or inductive components for resonance.

The cylindrical collar $\boldsymbol{g_C}$ with folded conductor ***c*** are connected to the ground plate ***g*** as shown in Fig. 3. It provides an eliminator for cross-sectional radiation.

The routing wires for feeding is formed on the surface of the substrate ***s*** under the ground plate **g**.

The overview of proposed single plane antenna is shown in Fig. 3.

Feed element ***a***:

In Fig. 3, the feed element *a* is made of a circular disc $2r_a$ with linear cutting $2r_{ac}$. It provides a dual resonator along the axes x and y. A long and short resonant wavelength are composed by the distance $2r_a$ and $2(r_a - r_{ac})$. The former and the latter correspond to the lower and the higher resonant frequencies f_L and f_H .

In Fig. 2, the distance d_a is kept close to the ground. Now the feed element ***a*** and the ground ***g*** form a microstripline resonator. The ground ***g*** provides the path for return current of the resonator ***a***.

Reactance element ***b***

The reactance element ***b*** is made of a circular disc shown in Fig. 3. It works as a reactive element providing inductive (delay in time) or capacitive (proceeding in time) effects to the resonator. This element works also as an antenna guide along *z* axis of the antenna.

The distance d_b is also kept short, which works as an added reactance component.

Cylindrical collar ***c***

The cylindrical collar *c* is connected to the ground plate ***g***. This collar flows revers current against the current of the reactance element ***b***.

Radiation from elements ***b*** and ***c*** are inverse mutually at far point from the origin of $x-y$ plane.

A quarter wavelength stripline with short circuit termination is composed by the cylindrical collar ***c*** and the ground plate ***g***. This configuration works as an eliminator of cross-sectional component of radiation.

Ground plate ***g***

The diameter of the ground plate ***g*** is three times or larger of the diameter of the feed element ***a***.

Cylindrical collar *c* and ground plate *g* are connected at the peripheral of the plane antenna.

Routing-wire substrate **s**

The substrate *s* should be prepared for routing-wire connected to the feed element ***a***.

The impedance of feeding must be 50Ω coaxial cable. This is made by thin dielectric substrate under the ground plate ***g***. By this configuration, microwave interference is cut by the ground ***g*** for forward direction of the *z*-axis.

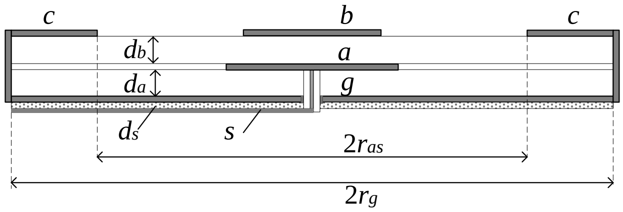

Fig.1 Cross setional view of the proposed antenna.
a : feed element, *b*: reactance element,
g : ground plate, *c* : cylindrical collar.

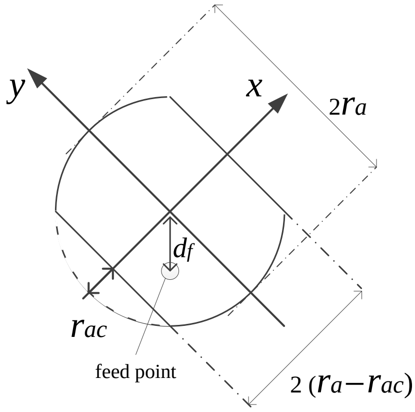

Fig. 2 Dimension of feeding element.

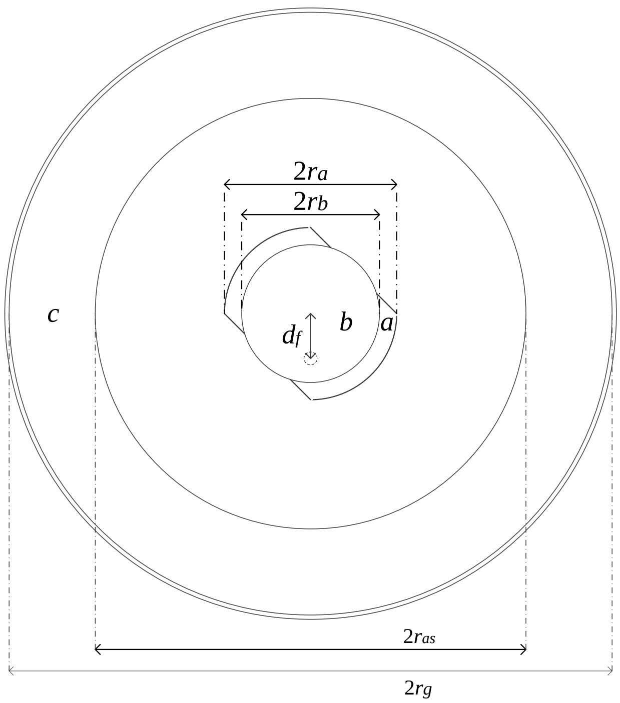

Fig.3 Configuration of proposed single antenna with ground extension.

2.2 Degeneration of two resonant modes

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 ;

$$f_L < f_M < f_H \qquad (1)$$

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*.

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

3 Novel Scheme of an Array Antenna

3.1 Required condition for circular polarization

Two resonant modes are needed along *x* and *y* axes for circular polarization. These resonant modes are given by a single disc with truncation.
Not only spatially but also temporally, the phase difference must be 90 degree between two modes.

This condition is realized by;
a) phase in space defined by the arrangement of antennas on $x - y$ plane, and
b) phase in time of feeding current through routing wires.

3.2 Arrangement in Space

A plane array antenna is shown in Fig. 4. An array is composed of four antennas a_i, (i = 1~4) at each quadrant around the center *O* in $X - Y$ plane. *Z* axis is perpendicular on *X*-*Y* plane. The *X*, *Y*, and *Z* axes form the Cartesian system. Transmission of circular polarized wave is vertical to the page and oriented here.

All antennas generate right-handed polarized wave. Two antennas in the first and the second quadrants are settled in parallel. Two antennas in the third and the forth quadrants are settled in anti-parallel as shown in Fig. 4.

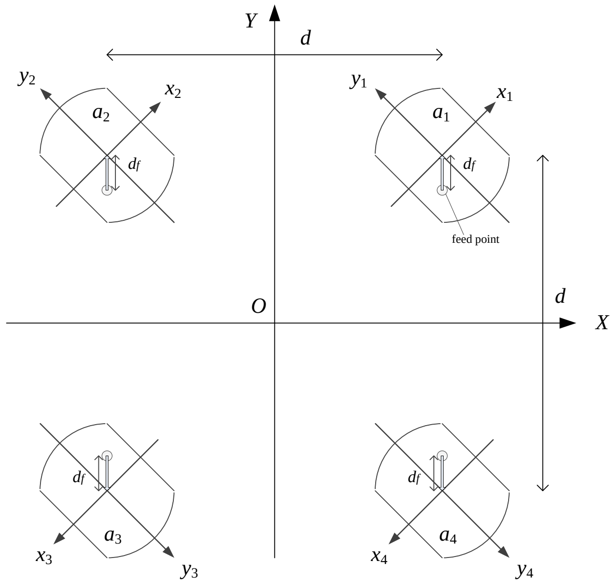

Fig. 4 Anti-parallel configuration of array antenna. Reactance elements and dielectric substrate are abbreviated.

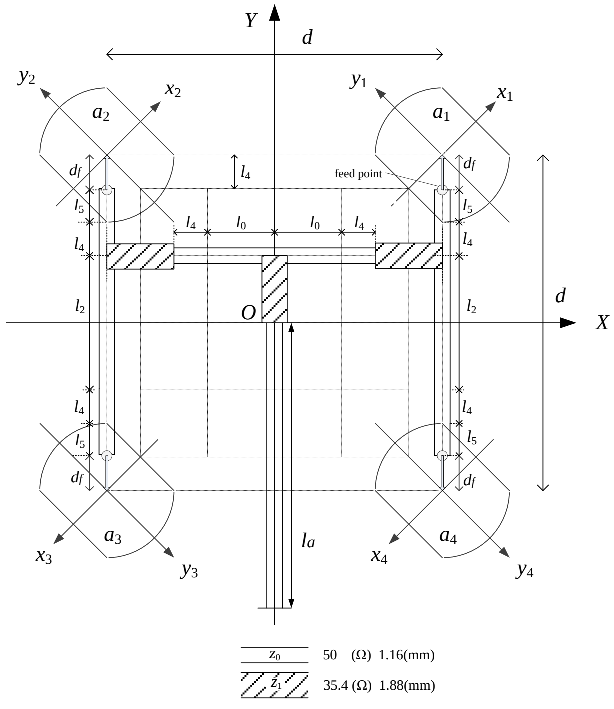

Fig. 5 Routing wire pattern for the proposed array antenna with 4 unit antennas.

The directions of Poynting vectors *pi* are defined according to the arrangement as shown in the figure. d_f shows the position of feeding point at each single antenna.

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

3.3 Feeding phase in Time

Feeding phases in time are defined by length of routing wires as shown in Fig. 5.

Single antennas at the first and the fourth quadrants are connected by different line length of routing wires. The difference of line length are half of λg corresponding to the phase difference 180 degree in time.

Single antennas at the second and the third quadrants are connected by different line length of routing wires. The difference of line length are half of λg corresponding to the phase difference 180 degree in time.

The length of routing wires feeding to the right and the left pair of antennas are the same.

Finally, the length of routing wire to the connector terminal should be defined to minimize the power of reflection.

The characteristic impedance of routing wire is designed by z_0 = 50 (Ω) of the NSA standard connector. The shadowed routing wires z_1 is designed for impedance matching with quarter wave length line.

4 Characteristics of the Proposed Array Antenna

The central frequency and the bandwidth are designed for the X-band. The array antenna is composed of 4 unit antennas.

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

The parameter values of the proposed antenna (unit) are;
The length of the resonator is 10.0 (mm) for lower frequency length, 7.0 (mm) for high frequency resonator. The diameter of reactance element is 8.0 (mm).

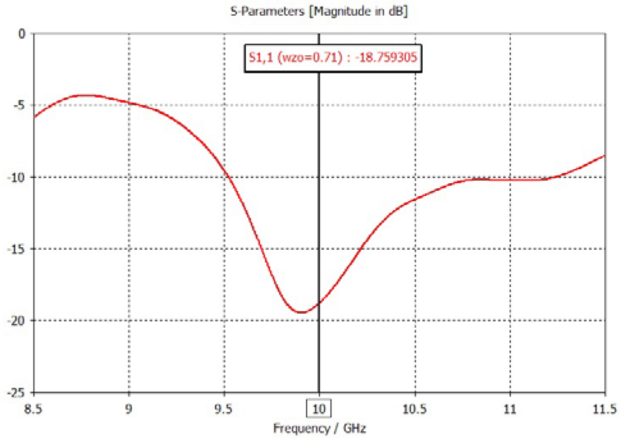

Fig. 6 Frequency characteristics of return loss.

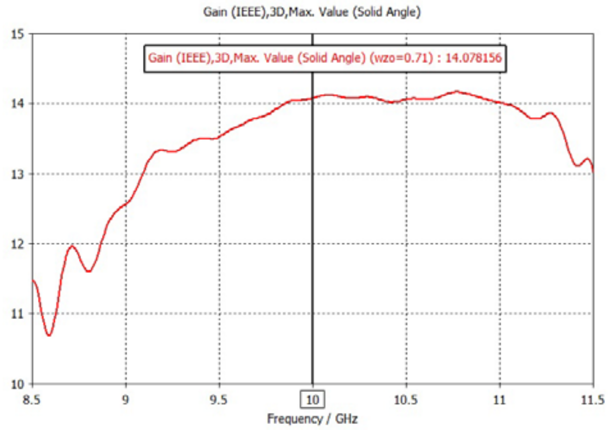

Fig. 7 Frequency characteristics of directive gain.

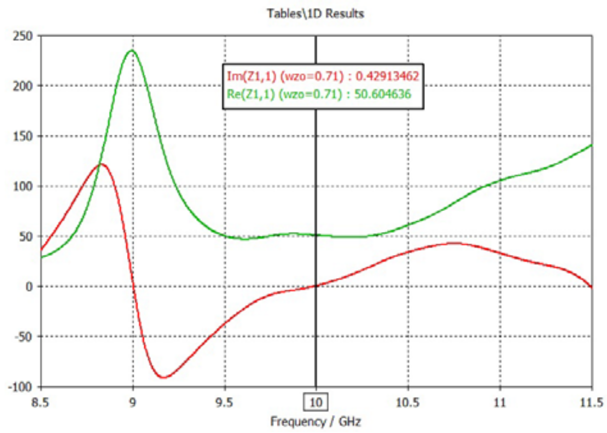

Fig. 8 Frequency characteristics of input impedance.
Upper line: real part of impedance.
Lower line: imaginal part of impedance.

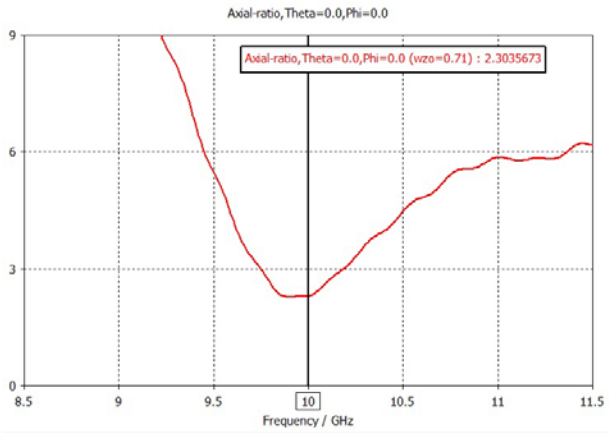

Fig. 9 Frequency characteristics of axial ratio of circular polarization.

The array configuration of unit antennas are perpendicular with each other along *x* and *y* axes. The spacing between unit antennas *d* = 25.0 (mm)

Frequency characteristics of the proposed array antenna are shown in Fig. 6~9 based on 3D computer simulation with CST Studio Suite.

(1) Return loss

The frequency characteristics of return loss is shown in Fig. 6.

The return loss is better than 15 dB between 9.5 ~ 11.2 GHz.

(2) Directive gain

The frequency characteristics of directive gain is shown in Fig. 7. The gain is higher than 13 dB between 9.1 ~ 11.5 GHz.

(3) Input impedance

The frequency characteristics of input impedance is shown in Fig. 8. The bandwidth of flat impedance is 9.4 ~ 10.7 GHz.

(4) Axial ratio

The frequency characteristics of axial ratio is shown in Fig. 9.

The axial ratio of circular polarization is smaller than 6 dB between 9.5 ~ 11.4 GHz. The bandwidth will be expanded by parameter tuning and increasing number of antennas in an array.

5 Conclusion

A novel scheme was presented to give simplified design with anti-parallel arrangement and simplified routing wire configuration for circular polarization array antenna. The novel configuration of the proposed scheme provides benefit of manufacturing to be applied for practical systems.

However the result of frequency characteristics are not enough in this paper, but it will be improved by parameter tuning and increasing number of antennas in an array.

This simplified scheme was confirmed to be applied to practical systems.

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