Circular Polarization Array Antenna with Orthogonal Arrangement and Parallel Feeding by Simplified Routing Wires

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Abstract: **-** This paper presents a wideband configuration of array antenna with orthogonal arrangement and parallel feeding by simplified routing wires for circular polarization. In conventional studies, the bandwidth of effective circular polarization and flat impedance was limited only as a few per cent of the central frequency. This paper presents first that a novel unit antenna is composed of feed, reactance, and ground elements to realize wideband and less spurious resonances. This paper presents secondly that the array is composed of four antennas arranged in orthogonal and fed in parallel with phase delays of 90 degrees for circular polarization. Based on computer simulation, it was first found that enough bandwidth is obtained for circular polarization. But it was also found that flat-impedance bandwidth is limited to compose a practical array antenna with multiple unit antennas.

Key-Words: **- C**ircular polarization, plane array antenna, orthogonal arrangement, smoothed routing wire, wideband characteristics.

1 Introduction

This paper describes a simplified configuration of circular polarized array antenna.

Conventionally linear polarized systems have been used for measurement and control systems together with telecommunication systems.

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

Conventionally, circular polarization antennas are limited in bandwidth at X-band.

The bandwidth of plane antennas have been only 2.2 ~ 2.4 % [1]. And recently a wideband antennas are studied for airplane and the other applications [2].

This paper provides simplified configuration of a four-antenna-array to provide high directive gain and wider bandwidth in input impedance with sequential scheme for routing wires to feed array with multiple antennas.

This paper presents simplified arrangement of parallel feeding for array with four antennas.

2 A Single Plane Antenna with Three Elements

2.1 Configuration of the proposed signle antenna

This antenna is made of three elements of ground plate (***g***), a feed element (***a***), and a reactance element (***b***) among microwave dielectric substrates. The length of the feed element is a half wavelength. The reactance element provides capacitive or inductive components for microwave resonation.

The configuration of the proposed antenna is shown in the overhead and the cross-sectional views of Fig. 1 and 2.

In Fig. 1, the diameters of feed- (***a***), reactance-elements (***b***), and ground plate (***g***) are $2r_a$, $2r_b$, and $2r_g$ respectively. In Fig. 2, 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.

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. 3, 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.

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

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.

2.2 Generation of circular polarization

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 ,

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.

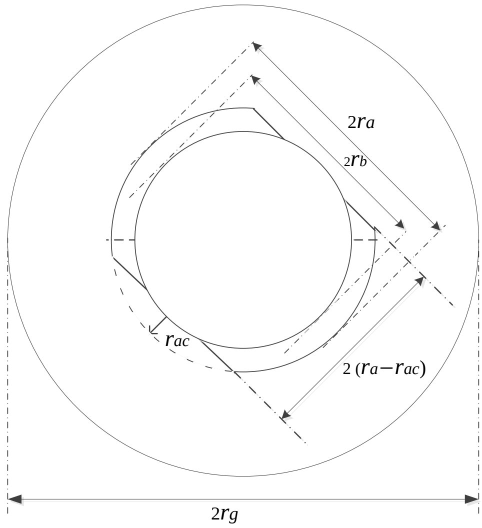

Fig. 1 Overhead view of the proposed antenna. The dimension of reactance element is included.

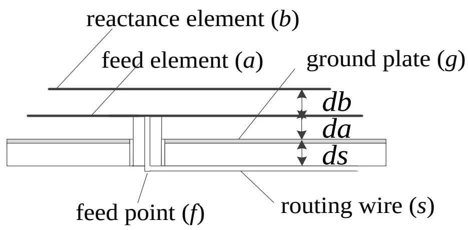

Fig. 2 Cross-sectional view of the proposed antenna.

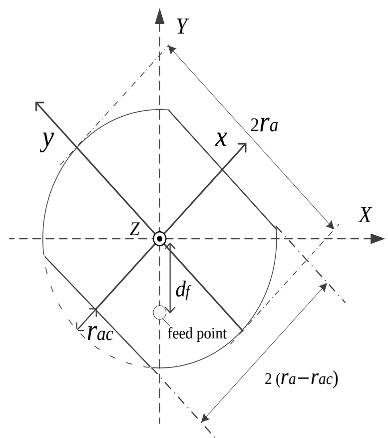

Fig. 3 Dimension of feeding element.

2.3 Characteristics of a Single Antenna

The proposed antenna was designed for the right-hand polarization. The following characteristics have been obtained by the simulation on CST STUDIO SUITE 2017.

(1) Return loss
The frequency characteristics of impedance matching by return loss is shown in Fig. 4. Matching bandwidth is 3 GHz for return loss 10 dB. The matching bandwidth of 30% is obtained at the central frequency.

(2) Gain of directivity
The frequency characteristics of power gain is shown in Fig. 5. It is found that any spurious radiation modes are not included between 9 to 11 GHz.

(3) Axial ratio
The frequency characteristics of axial ratio is shown in Fig. 6. Where, axial ratio is defined by the ratio in dB of electric field strength along *x* and *y* axes. The bandwidth of 0.7 GHz (7%) was obtained.

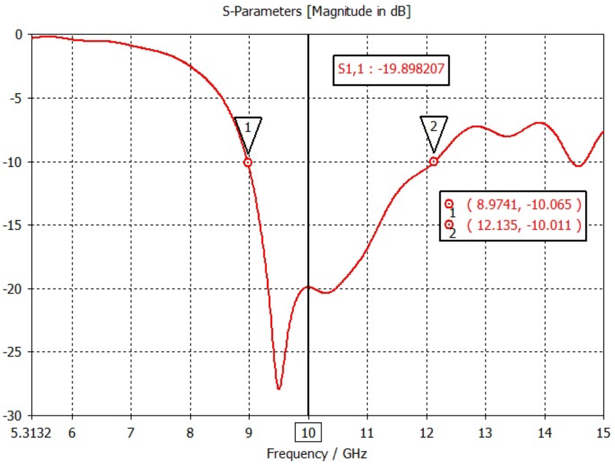

Fig. 4 Return loss

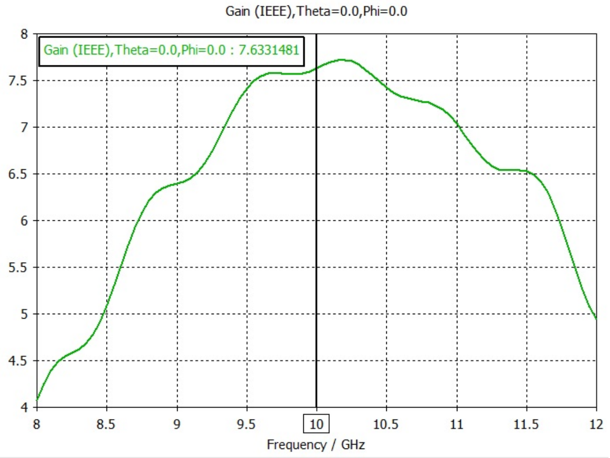

Fig. 5 Gain of directivity.

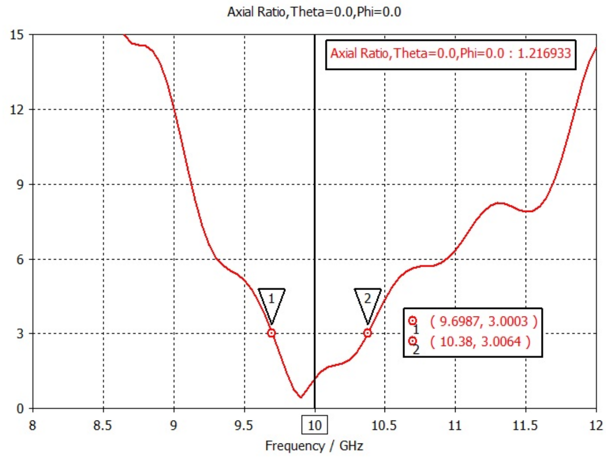

Fig. 6 Axial ratio.

3 Array Antenna with Four Plane Antennas

3.1 Configuration of the proposed array antenna

A plane array antenna is shown in Fig. 7. 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.

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 left-handed circulation. The directions of Poynting vectors *pi* are defined according to the orthogonal arrangement as shown in the figure. d_f shows the position of feeding point at each unit antenna.

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

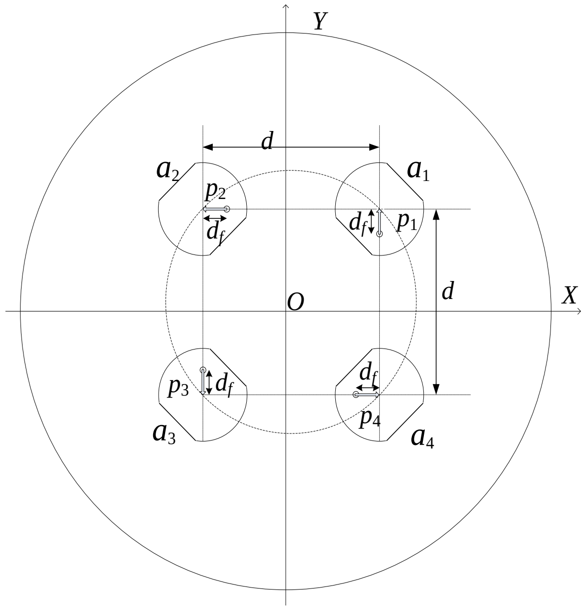

Fig. 7 Configuration of plane array antenna. Reactance elements and dielectric substrate are abbreviated.

3.2 Routing wire configuration

The configuration of routing wires is shown in Fig. 8. This scheme gives are simplified configuration of routing wire to feed four antennas for circular polarization.

It is pointed that the 90 degree phase difference is needed between adjacent antennas for circular polarization in Fig. 8. Four antennas are allocated on orthogonally with each other along X and Y axes.

The antenna pairs a1 and a4, and a2 and a3 are connected first with 90degree phase difference.

The right pair is connected to the left pair each other with the phase delay (180°) which leads to the input port (upper).

The white line is defined by 50 Ω. The shadowed line is quarter wave length matching section which matches 50 (parallel of two 50 Ω),.

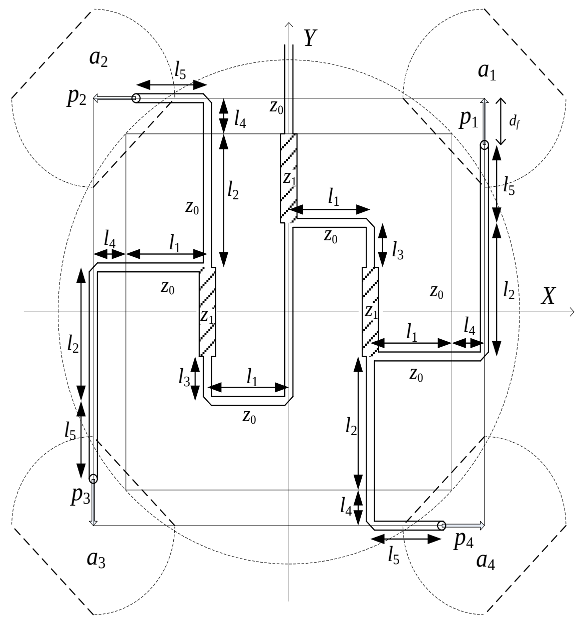

Fig. 8 Routing wire pattern for the proposed array antenna with 4 unit antenns.

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).

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. 9~12 based on 3D computer simulation with CST Studio Suite.

(1) Return loss
The frequency characteristics of return loss is shown in Fig. 9.

The return loss is better than 15 dB between 9.2~ 10.7 GHz.

(2) Directive gain
The frequency characteristics of directive gain is shown in Fig. 10.

The gain is higher than 10.5 dB between 8.8 ~ 10.7 GHz.

(3) Input impedance
The frequency characteristics of input impedance is shown in Fig. 11. The source impedance is 50 Ω. The upper and the below curves are real and imaginary parts of complex impedance. The bandwidth of flat impedance is very narrow. Then this brings difficulty for integration of multiple antennas.

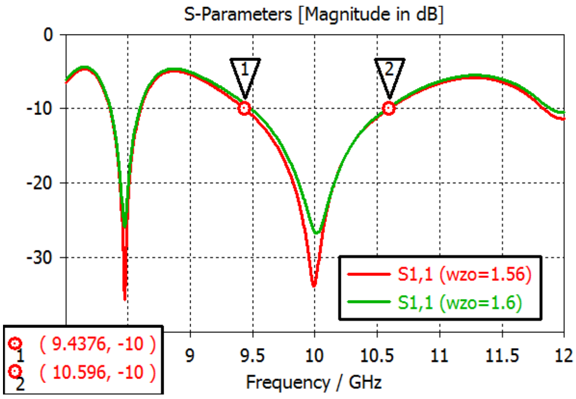

Fig. 9 Frequency characteristics of return loss.

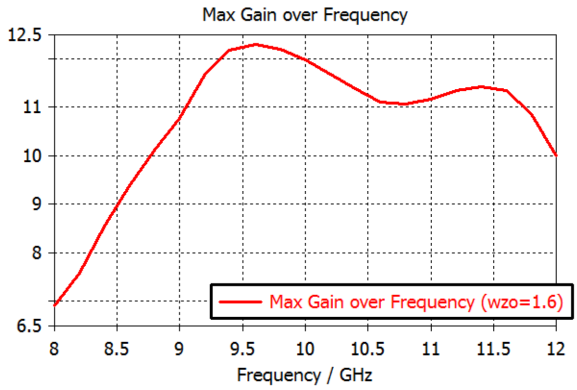

Fig. 10 Frequency characteristics of directive gain.

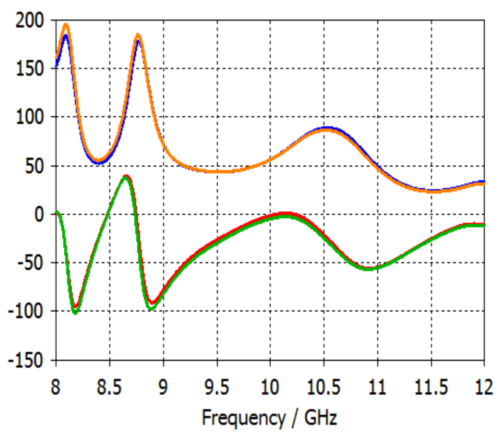

Fig. 11 Frequency characteristics of input impedance.
Upper line: real part of impedance.
Lower line: imaginal part of impedance.

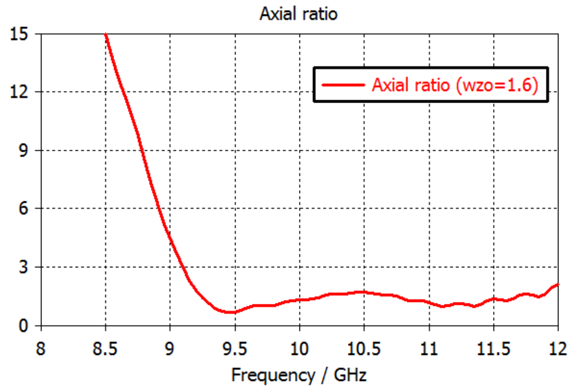

Fig. 12 Frequency characteristics of axis ratio of circular polarization.

(4) Axis ratio
The frequency characteristics of axis ratio is shown in Fig. 12.

The axis ratio of circular polarization is smaller than 3 dB between 9.1 ~ 11.3 GHz. And frequency band is not narrow but wide enough for practical use.

5 Conclusion

A configuration of routing wires for circular polarization array antenna was presented in this paper. The configuration of routing wire was simplified to reduce the length of transmission line. However the result of frequency characteristics of input impedance was not wide but narrow against the array antenna with multiple antennas. IThis simplified configuration was found not applicable to practical array antenna systems.

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