Simplified Routing Wire for Anti-Parallel Configuration Applied to Circular Polarization 16-Antenna Array

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Abstract: -This paper presents a simplified routing wire for anti-parallel configuration. This scheme is applied to parallel feedings to a circular polarization 16-antenna array. The unit antenna is composed of three elements of feed and reactance elements, and ground plate. Then, a configuration of 16-antenna array is presented. A 4-antenna array composed of smoothed routing wire is set at each quadrant. The directions of each 4-antenna array at the first and the second quadrants are parallel, and anti-parallel at the third and the fourth quadrants. A grounded circular cylinder is set at the peripheral of 16-antenna array. 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 expected to be used to remote sensing and control of environmental applications.

The authors have studied essential technologies to compose miniaturized and high performance antenna and sensor systems [1-7].

Novel scheme of simplified configuration was presented in the paper [7]. It is composed of anti-parallel arrangement of 4-antenna array with simplified feeding routing wire. The effect of novel configuration has not been clarified yet. And the effects of the parameter values have not been clarified also.

This paper presents a result of application into array system proposed and studied by the authors.

2 Configuration of the Proposed Unit 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. 1. 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. 2, 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. 1 and 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 50 (Ω) 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.

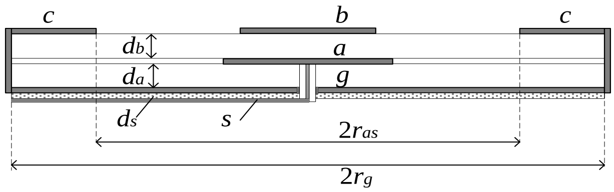

Fig.1 Cross setional view of the proposed antenna.
a : feed element, *b*: reactance element,
g : ground plate, *c* : cylindrical collar.

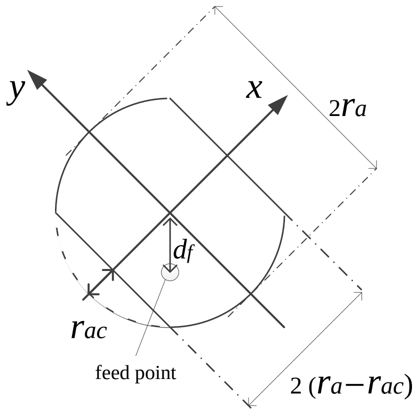

Fig. 2 Dimension of feeding element ***a***.

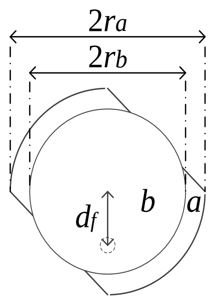

Fig.3 Configuration of proposed single antenna with reactance element ***b***.

3 Novel Scheme of a 4-Antenna Array

3.1 4-Antenna array of orthogonal arrangement with smoothed routing wire

This scheme is composed of orthogonal arrangement of 4 antenna array and smoothed routing wires for feeding. A 4-antenna array is shown in Fig. 4. 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 left-handed circulation. d_f shows the position of feeding point at each antenna.

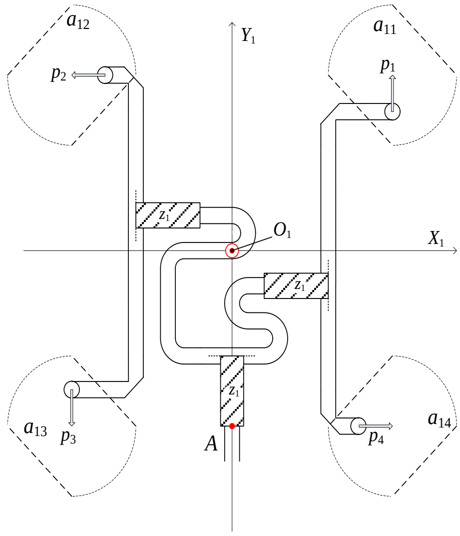

Fig. 4 Routing wire pattern for a 4- antenna array with orthogonal arrangement.

3.2 4-Antenna array of anti-parallel arrangement with simplified routing wire

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.

A plane array antenna is shown in Fig. 5. 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. 5.

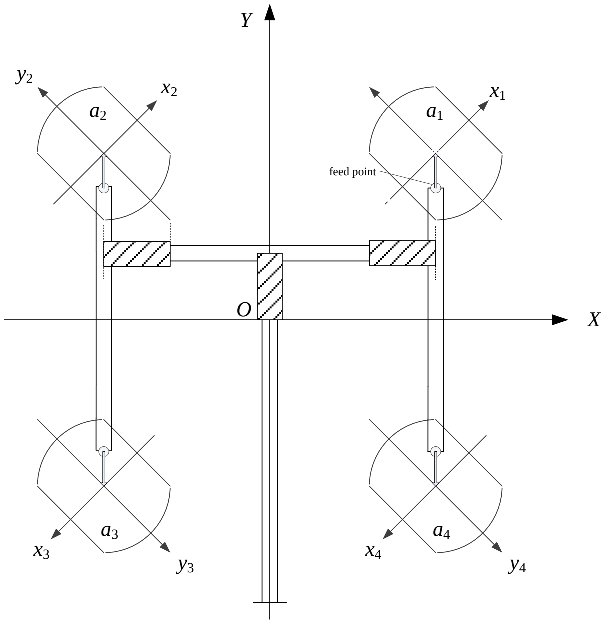

Fig. 5 Routing wire pattern for 4-antenna array with anti-parallel arrangement.

4 Anti-Parallel Arrangement Applied to 16-Antenna Array

4.1 Anti-Parallel Arrangement of Four Antenna Arrays

A novel scheme of 16-antenna array is shown in Fig. 6. This scheme realizes an anti-parallel arrangement of antennas allocated at each quadrant.

Individual antenna forms orthogonal arrangement in each quadrant. On the other hand, each antenna array is set in parallel arrangement.

In Fig. 6, the simplified routing wire shown in Fig. 5 is used to realize anti-parallel arrangement in four-antenna array.

But individual antenna in each quadrant is composed of orthogonal arrangement shown in Fig. 4. It is pointed that the novel configuration presents unknown results of mixed configuration of orthogonal and anti-parallel arrangement in a 16-antenna array.

4.2 Elimination of cross-sectional radiation

A grounded cylindrical collar is shown at the peripheral of the array in Fig. 6. This collar forms a quarter wavelength line with short termination. Cross-sectional microwave radiation is eliminated. This is set to match the impedance of cross-sectional radiation. This is connected to the stripline ground plate.

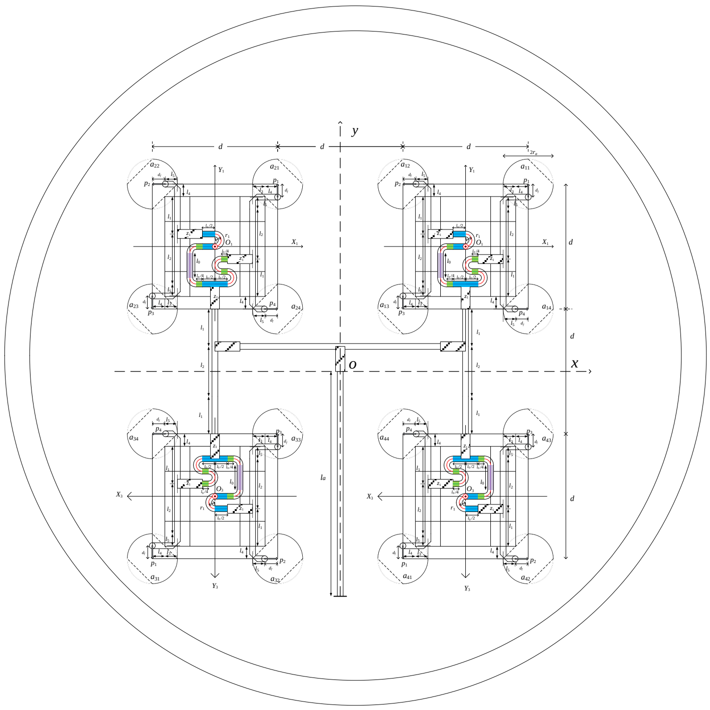

Fig. 6 16-antenna array with anti-parallel arrangement and grounded cylindrical collar. Smoothed Routing wires are used for 4-anttena array in the each quadrant, and simplified routing wire for 4x4--antenna array.

5 Characteristics of the Proposed Array Antenna

5.1 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.

5.2 Characteristics and evaluation

Frequency characteristics of the proposed array antenna are shown in Fig. 7 ~ 11. Where, red, green, blue lines correspond to width of input matching lines of impedances 40, 50, and 60 (Ω) approximately. 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. 7. The return loss is better than 10 dB between 9.7~ 11.3 (GΩΩ).

(2) Directive gain

The frequency characteristics of directive gain is shown in Fig. 8. The proposed configuration gives maximum gain 17.3 dB.

(3) Input impedance

The frequency characteristics of input impedance is shown in Fig. 9. The source impedance is 50 (Ω). The upper and the below curves are the real and the imaginary parts of complex impedance. Real impedance (brawn line) is 40 ~ 50 (Ω) approximately. Imaginary impedance (blue line) is -20 ~ +25 (Ω) approximately between frequency from 9.8 to 10.8 (GHz).

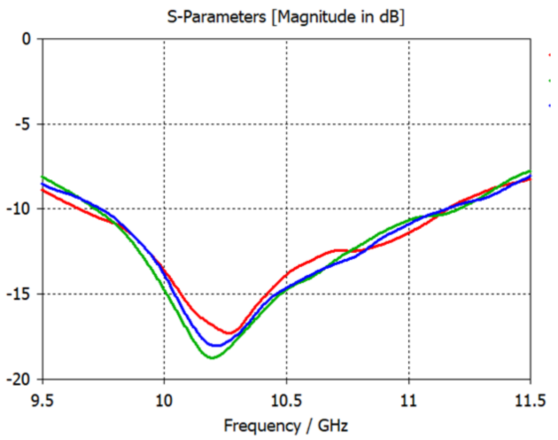

Fig. 7 Frequency characteristics of return loss.

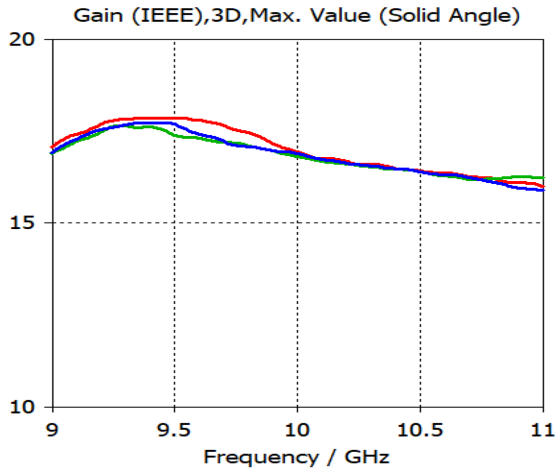

Fig. 8 Frequency characteristics of directive gain.

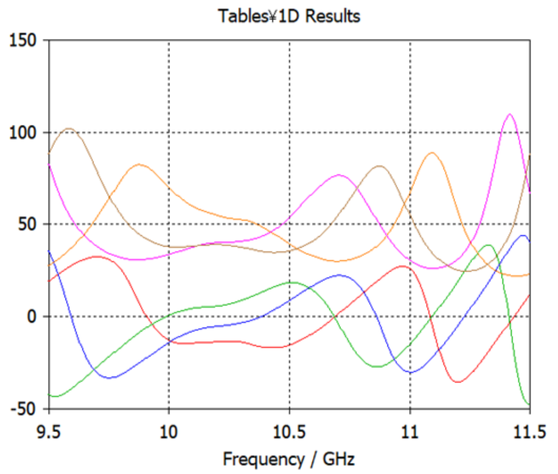

Fig. 9 Frequency characteristics of input impedance.
Upper line: real part of impedance.
Lower line: imaginal part of impedance.

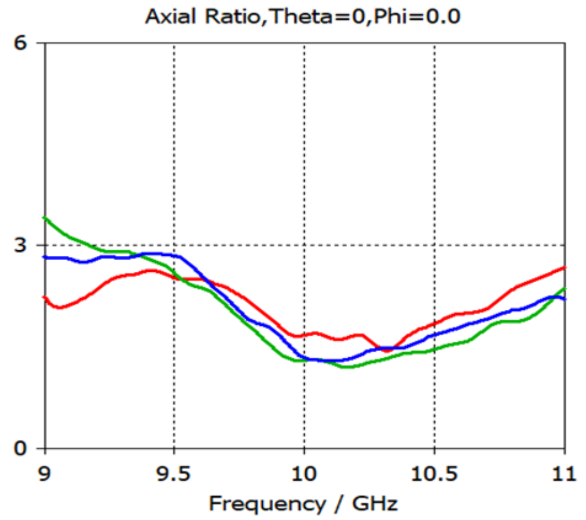

Fig. 10 Frequency characteristics of axial ratio of circular polarization.

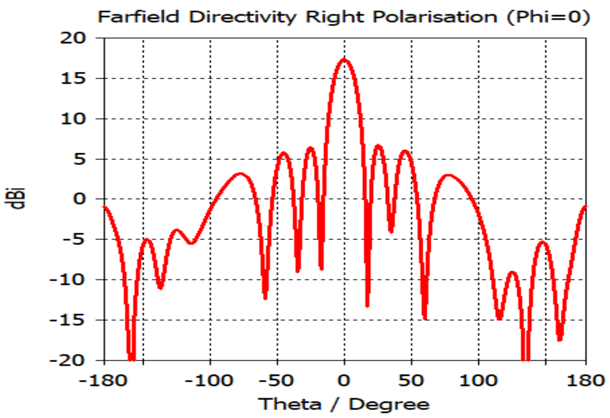

Fig. 11 Farfield directive gain for circular polarization.

(4) Axial ratio

The frequency characteristics of axial ratio is shown in Fig. 10. The axial ratio of circular polarization is smaller than 3 dB between 9.2 ~ 11 (GHz).

(5) Farfield directive gain

The far field directive gain is given by polar scale in Fig. 11. The side lobe level was −10.6 dB from the main lobe. It means sharp beam of radiation was given. It was found that the directive gain of this array was 17.3 dB which is 2 dB approximately better than the gain without the grounded collar.

6 Conclusion

A novel scheme of 16-antenna array was presented in this paper. This array is composed of anti-parallel configuration of 4-antenna array set at each quadrant. 4-antenna array at each quadrant have been studied developed by the authors presented in former papers [7].

When the above 4-antenna array is regarded as a set of antenna, the newly developed configuration of 4-antenna set in 4 quadrants are taken as arranged according to the novel scheme given in this paper and for the former paper [7].

It was confirmed in this study that high farfield gain are about 17.3 dB, and the bandwidth of axial ratio is 15% at 1.8 ~ 10. 8 (GHz) at 10 (GHz). It is concluded that these values are a little lower but equivalent approximately compared to the scheme presented in paper [8]. But we will continue this study to have the better data.

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