16-Antenna Array for Circular Polarization with Wideband Axial Ratio and Enhanced Directivity

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Abstract: - This paper presents a novel structure of circularly polarized 4-antenna array and its expansion to 16-antenna array. First a novel configurations are given of a single antenna and a 4-antenna array with orthogonal arrangement fed by S-type routing wire. S-type routing wire was found to have capabilities of minimizing and cancelling reflections mutually between both sides of parallel feeding lines. Then, 16-antenna array is given by the above 4-antenna array settled on four quadrants. Grounded collars at the peripherals of antenna arrays operate to eliminate cross-sectional radiations. The characteristics of the proposed antenna array are given by 3D computer simulation. Extremely wideband axis ratio was first realized with 10 times wide bandwidth compared to conventional plane antennas.

Key-Words: - Wideband circular polarization antenna, orthogonal arrangement, S-type routing wire, grounded collar at peripheral, elimination of cross-sectional radiation.

1 Introduction

Microwave transmission using circular polarization has various utilities for remote sensing of environments, geography, resources. Microwave circular polarization plane antenna using stripline structure is compact and applied easily to moving vehicular and airplane, and so on.

Conventionally, truncated rectangular plates or circular discs are used for stripline resonator antennas[1]. “Truncation” provides one disc with two resonant frequencies f_L and f_H., which correspond to the band edges of circular polarization. A square slit set at the center of circular disc realizes stripline circular polarization antenna. But the useful bandwidth were so narrow as 2 % of the central frequency at 10 GHz X-band.

This paper describes novel scheme for wideband and enhanced directivity of compact antennas. This scheme composed of wideband antenna using three layers stripline resonator, orthogonal arrangement of 4 antenna array, routing wire by S type feeding, and cross-sectional eliminator with grounded cylindrical collar, and so on[2-7].

Configuration of 16-antenna array and its characteristics is given in this paper based on 3D computer simulation.

2 A Single Plane Antenna

2.1 Structure of a proposed single antenna

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. 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. 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. 4. 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.

2.2 Degeneration of two resonant modes and their frequencies

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***.

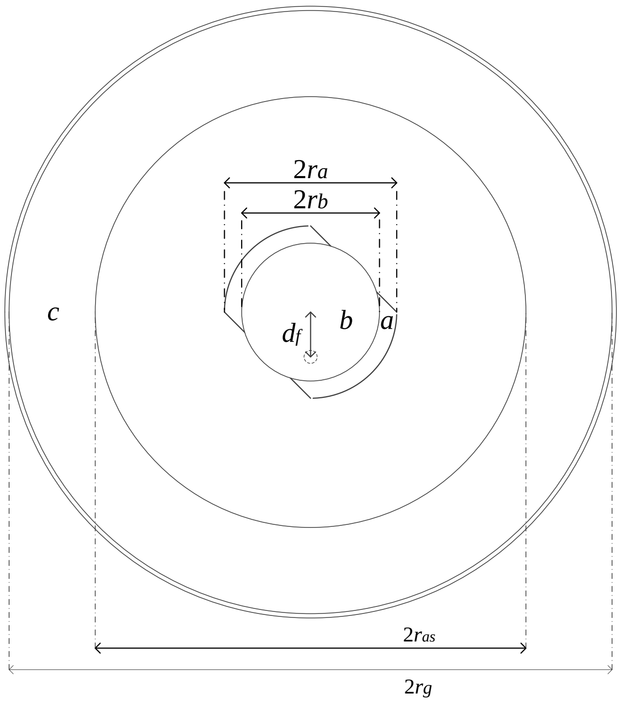

Fig.1 Configuration of proposed single antenna with ground extension.

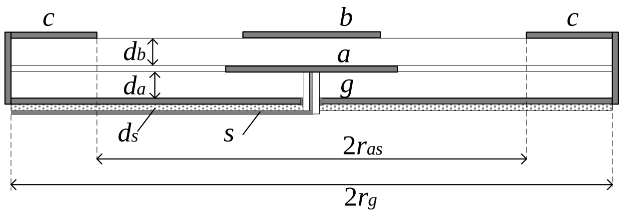

Fig.2 Cross setional view of the proposed antenna.
a : feed element, *b*: reactance element,
g : ground plate, *c* : cylindrical collar.

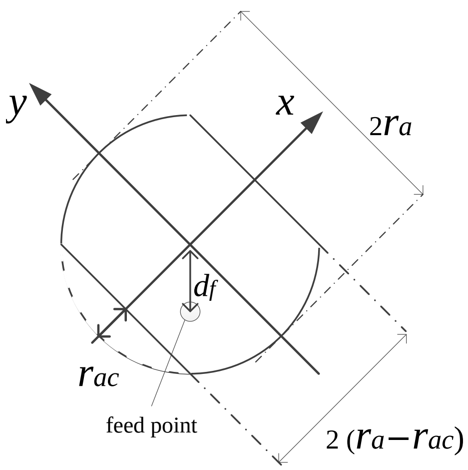

Fig. 3 Main element *a* with feeding.
df: Feeding point.

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 Spatial arrangement

An array antenna 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.

The diameter of the ground plate $2rg$ 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. 4. This scheme forms a parallel composition of routing wire.

The condition of 90 degree phase difference are given between right hand elements $a1$ vs $a4$, and the left hand elements $a3$ vs $a2$. At the connection of the right and the left elements, 180 degree and 90 degree phase delay are provided by corresponding line lengths.

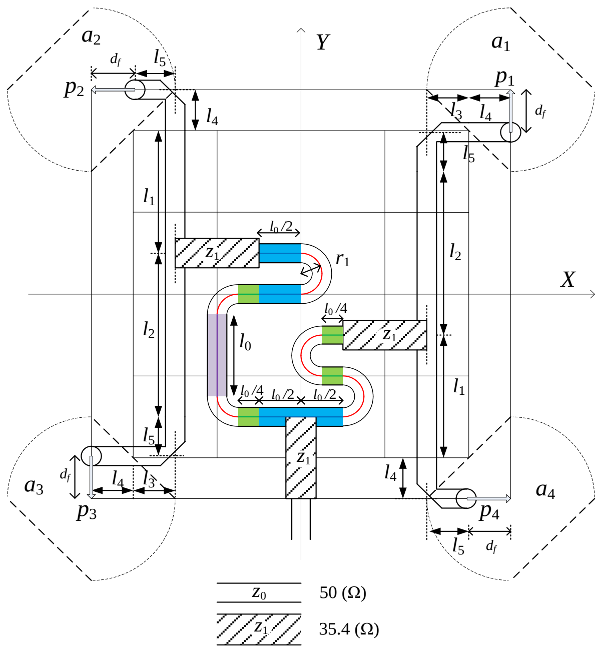

Fig. 4 Routing wire pattern for the proposed array antenna with four (4) antennas.

4 16-Antenna Array

4.1 Spatial arrangement

The Cartesian system x- y – z is used. 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.

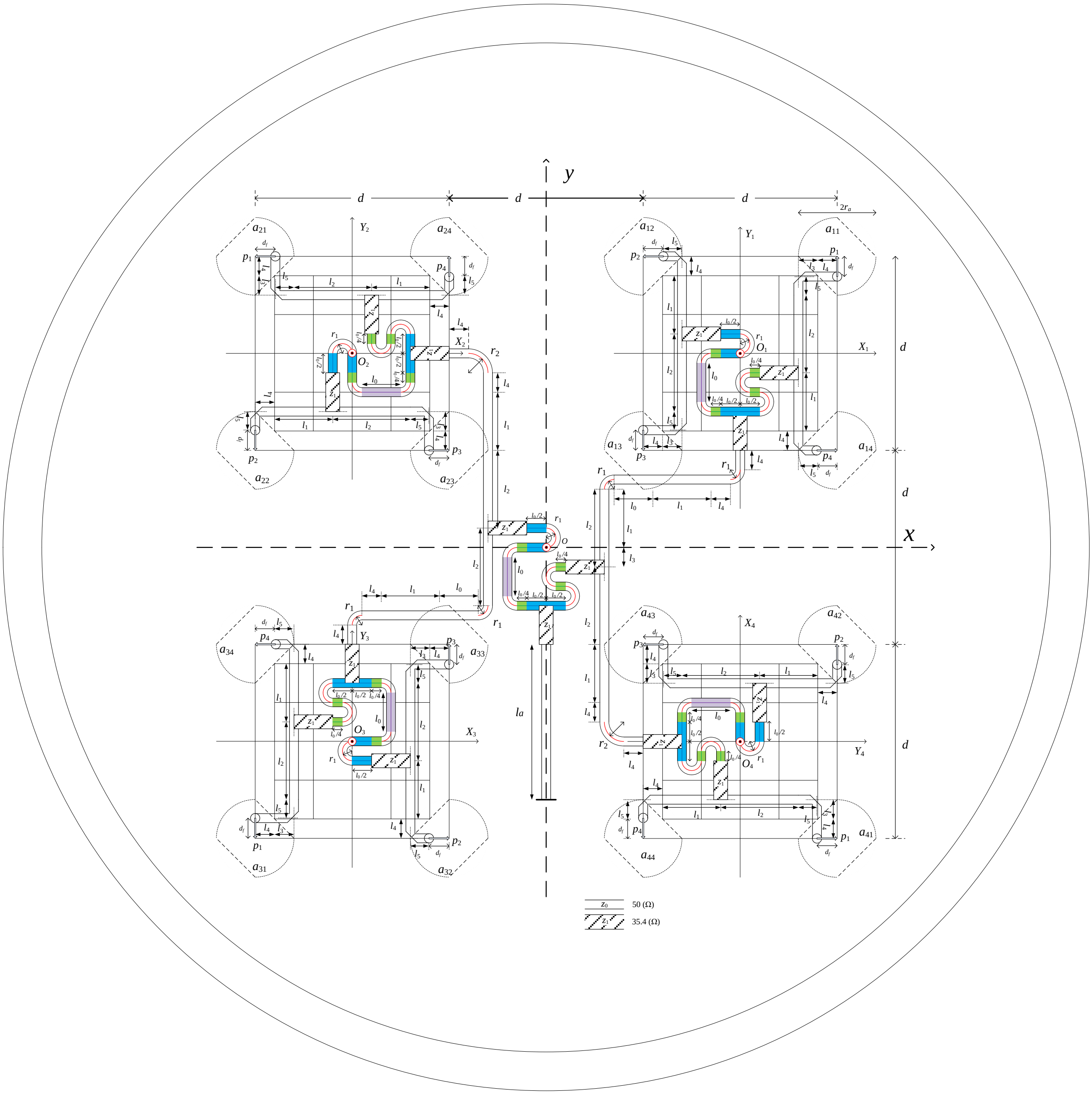

Fig. 5 Spatial arrangement routing wires for feeding of 16 antenna array.
Four-antenna array given in Fig. 4 is allocated in each quadrant with 90 degrees right hand turn.

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 between antennas along *x* and *y* axes is *d* = 25.0 (mm).

5.2 Characteristics and evaluation

Frequency characteristics of the proposed array antenna are shown in Fig. 6 ~ 10. 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. 6. 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. 7. The proposed configuration gives maximum gain 17 dB.

(3) Input impedance

The frequency characteristics of input impedance is shown in Fig. 8. The source impedance is 50 Ω. The upper and the below curves are the real and the imaginary parts of complex impedance. Extremely wide and flat input impedance was obtained from 9.4 to 10.6 GHz. It proves that larger size array antenna becomes practical by this paper.

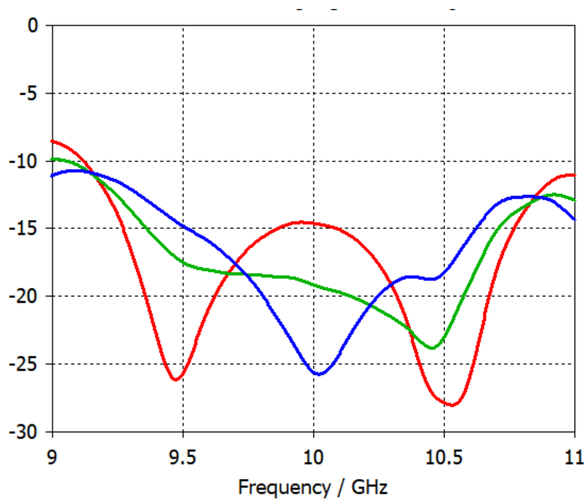

Fig. 6 Return loss (dB).

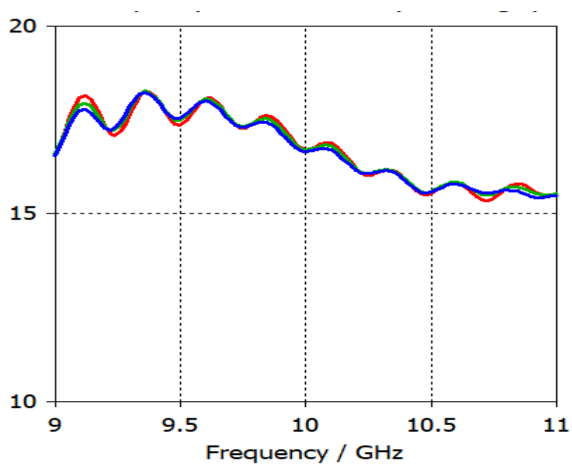

Fig. 7 Maximum gain (dB).

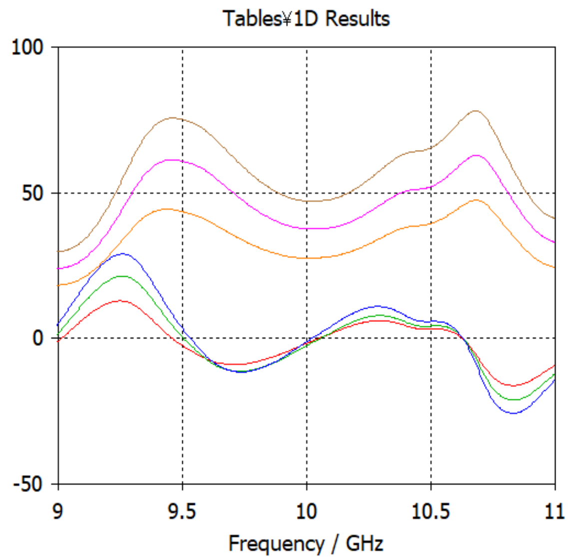

Fig. 8 Input impedance (Ω).
upper lines : real part
lower lines: imaginal part

(4) Axial ratio

The frequency characteristics of axial ratio is shown in Fig. 9. The axial ratio of circular polarization is smaller than 3 dB between 9 ~ 11.5 GHz. The axial ratio shows small and wideband characteristics of circular polarization at X band.

(5) Farfield directivity

The far field directivity is given by polar scale in Fig. 10. The side lobe level was −8.8 dB from the main lobe. It means sharp beam of radiation was given.

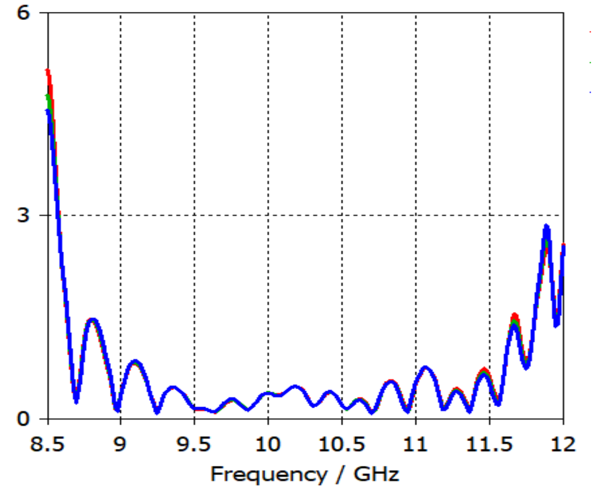

Fig. 9 Axial ratio (dB).

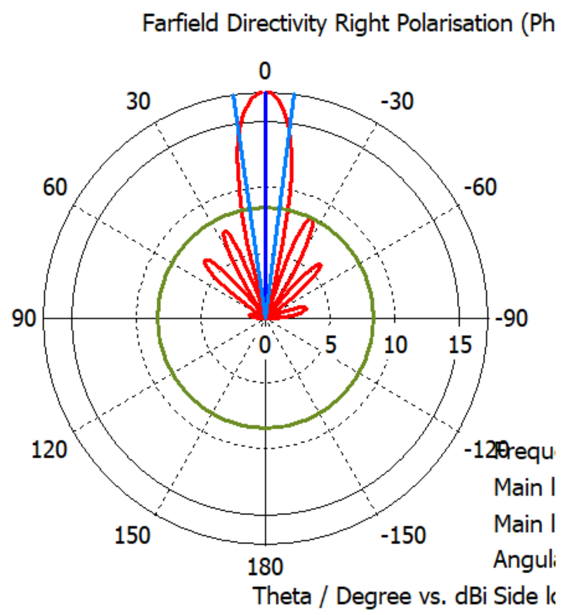

Fig. 10 Farfield directivity (dBi).

6 Conclusion

A novel configurations were given of a single antenna and a 4-antenna array with orthogonal arrangement fed by S-type routing wire. S-type routing wire was found to have capabilities of minimizing and cancelling reflections mutually between both sides of parallel feeding lines.

Then, 16-antenna array was given by the above 4-antenna array settled on four quadrants.

Grounded collars at the peripherals of antenna arrays were found to eliminate cross-sectional radiations effectively.

The characteristics of the proposed antenna arrays were given by 3D computer simulation. Extremely wideband axis ratio was first realized with 10 times wide bandwidth compared to conventional plane antennas.

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