Circular Polarization 16-Antenna Array with Smoothed Routing Wires and Grounded Square Collar

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Abstract: - This paper presents a novel configuration of circular polarization 16-antenna array. A novel configurations of a single antenna is presented first. Then a 4-antenna array is given based on orthogonal arrangement and smoothed (S-type) routing wire for feeding. Then, 16-antenna array is given by the above 4-antenna arrays which are settled in four quadrants. Grounded square collar is newly proposed at the peripheral of the array. This collar eliminates cross-sectional radiation and enhances the forward directive gain effectively. Extremely wideband axis ratio was first realized 10 times wider than conventional plane antennas. The directive gain also have been enhanced 2.5 dB approximately, which reduces the number of antennas into half for an array.

Key-Words: - Wideband circular polarization antenna, orthogonal arrangement, S-type routing wire, grounded square 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 so on.

Conventionally, truncated rectangular plates or circular discs are used for stripline resonator antennas[1,2]. “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.

Novel configuration of circular polarization array antenna is given in this paper based on grounded square collar for 16-antenna array. This configuration provides stable conditions to the eliminators around all antennas at the peripheral set at equal distances.

2 A Single Plane Antenna

2.1 Composition of a 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. 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. 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, df shows the distance of the feed point from the center of feed element.

In Fig. 1, 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. 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.

Ground plate ***g***

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

Grounded collar ***c***

The collar *c* is connected to the ground plate ***g***. This collar eliminates radiated energy from the antenna made of a half wavelength stripline resonator, This resonator is made of feed element ***a***, reactance element ***b***, and ground plate ***g***.

Forward (*z*-axis) and cross-sectional (*x*–*y* domain) radiation energy is radiated dominantly through reactance element ***b.***

Cross-sectional radiation energy is composed by components of central antenna itself and collar radiated from ***b*** and ***c*** set at the upper surface. Cross-sectional radiation energy from ***b*** and ***c*** correspond to radial and angular current components. The component of radial current of antenna is eliminated by quarter wavelength line with short termination.

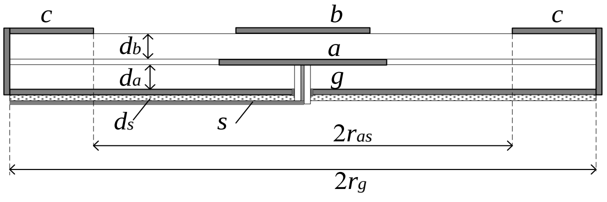

Fig.1 Cross setional view of the proposed antenna.
a : feed element, b: reactance element,
g : ground plate, c : grounded collar.

The phase of the angular current of antenna and collar are inverse and cancel each other. It is also pointed that forward radiation energy are enhanced inside the collar and reduced outside the collar. It brings high directional gain and low sidelobe level.

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.

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 ;

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

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***.

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.

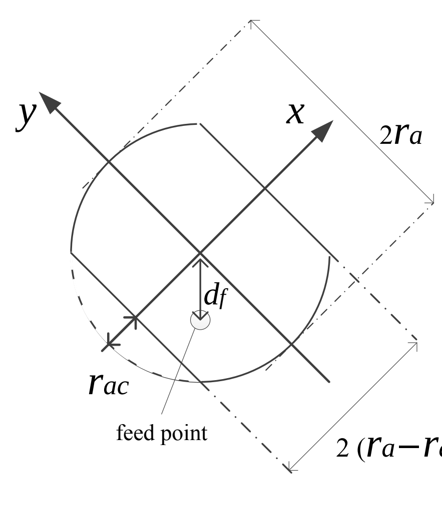

Fig. 2 Main element a with feeding.
df: Feeding point.

3 Four-Antenna Array

3.1 Configuration of 4 antenna attay

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. 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 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.

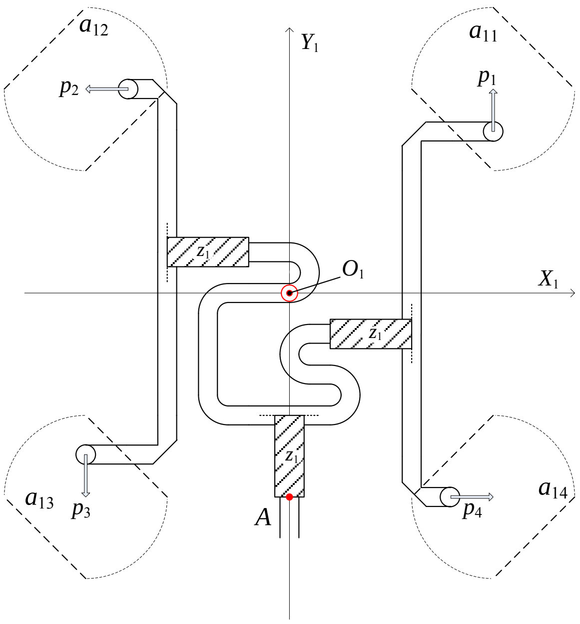

Fig. 3 Smoothed routing wire for a 4-antenna a_{11} ~ a_{14}, and p_1 ~ p_4 are feeding Poynting vectors at the first quadrant. O is the centre of the plane X_1-Y_1. A is the input point of feeding. z_1 and z_0 are characteristics impedances of routing wires.

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 $a1$ 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.

4 16-Antenna Array with Grounded Square Collar

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.

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.

It is pointed that elimination of cross-sectional radiation energy contributes to increase forward radiation energy. Finally it provides enhancement of forward directive gain.

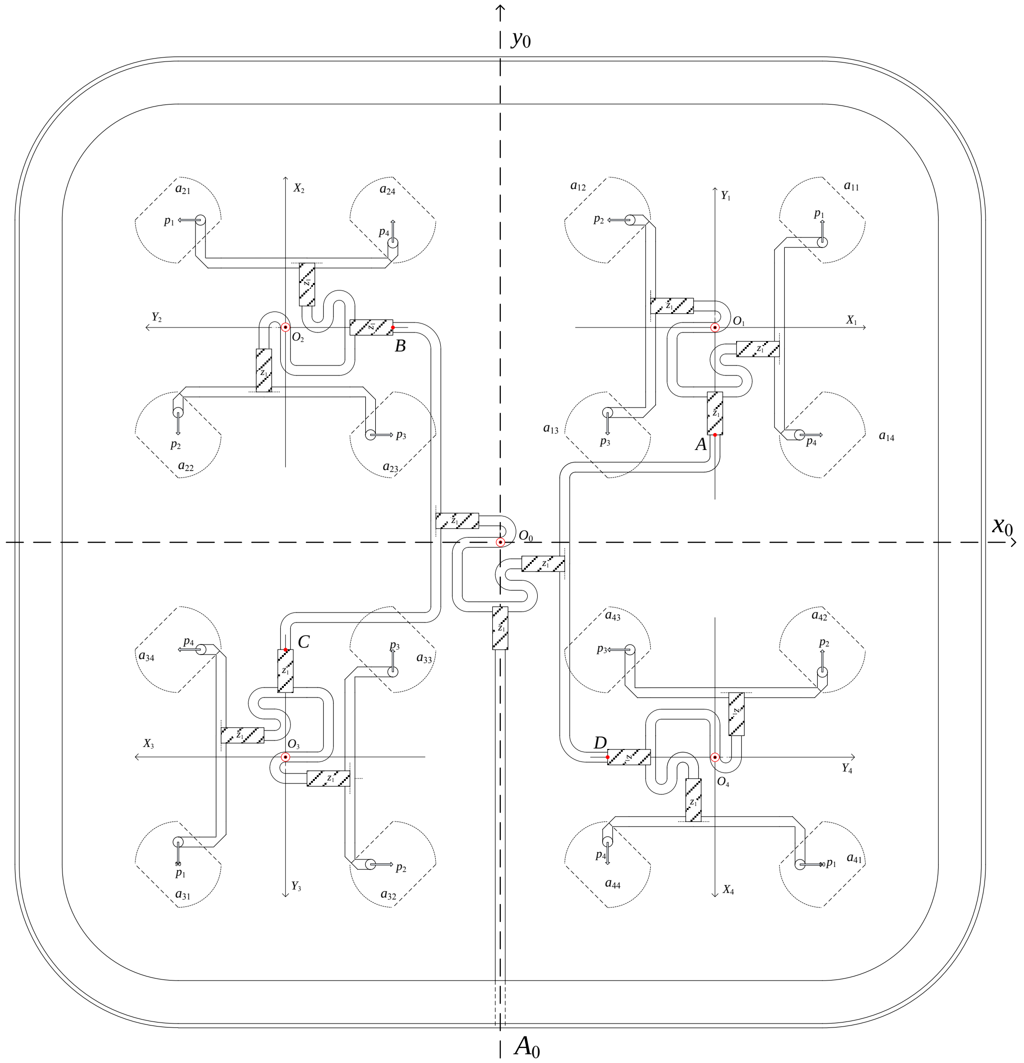

Fig. 4 Circular polarization array antenna with 16 antennas and grounded square collar. The 4-antenna array is allocated in each quadrant with right hand turning 90 degrees. Microwave input port is shown as A_0.

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. 5 ~ 9. 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. 5. The bandwidth of return loss 10 (dB) is 2 (GHz) or more.

(2) Directive gain

The frequency characteristics of directive gain is shown in Fig. 6. The proposed configuration gives maximum gain 18.3 (dB) approx.

(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. 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.

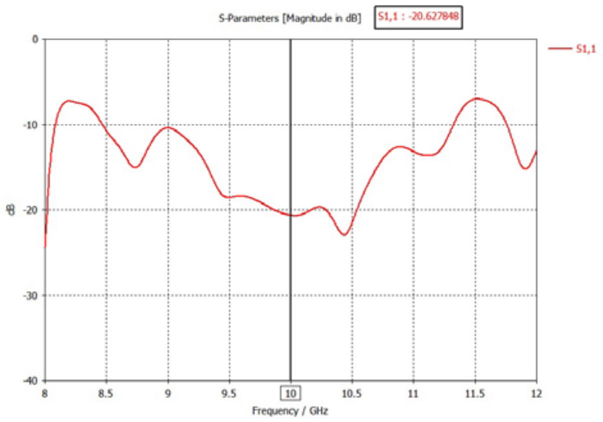

Fig. 5 Return loss (dB).

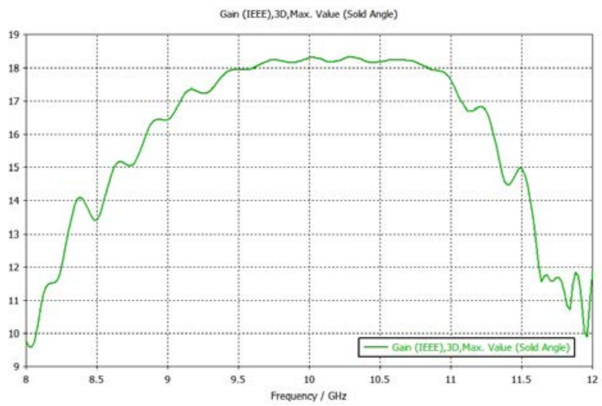

Fig. 6 Maximum gain (dB).

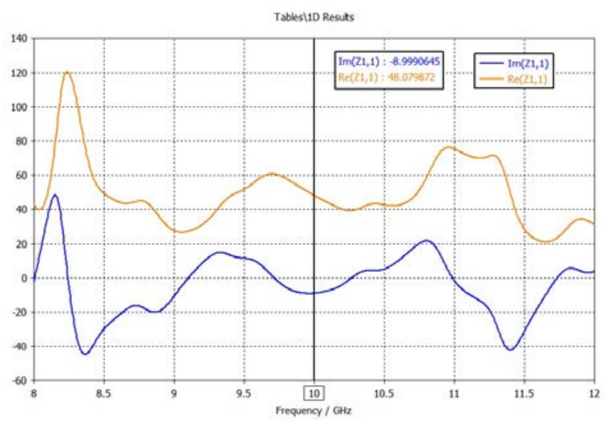

Fig. 7 Input impedance (Ω).
upper lines : real part
lower lines: imaginal part

(4) Axial ratio

The frequency characteristics of axial ratio is shown in Fig. 8. The axial ratio of circular polarization is smaller than 3 (dB) between 9 ~ 11.5 (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. The side lobe level was −8.8 (dB) from the main lobe. It means sharp beam of radiation was given. It was found that the directive gain of this array was 18.8 (dB) which is 2.5 (dB) approximately better than the gain without the grounded square collar.

It shows the needed number of (ex. 32) antennas of an array is reduced to half (ex. 16) of conventional design. This contributes miniaturize remarkably the dimension of array.

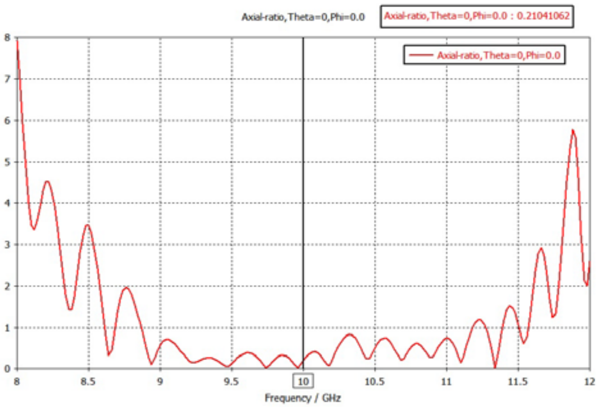

Fig. 8 Axial ratio (dB).

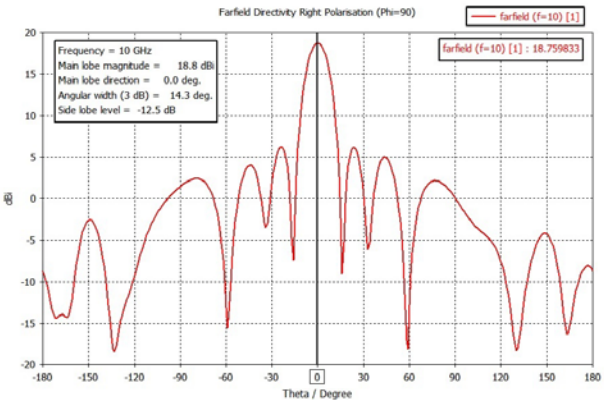

Fig. 9 Farfield directivity (dBi).

6 Conclusion

A novel configurations was presented for a single antenna and a 4-antenna array with orthogonal arrangement fed by S-type routing wires.

S-type routing wire provides 16- or more antenna array with extremely wideband input impedance and axial ratio. The grounded square collar reduces the number of antennas in an array into about half of antennas needed by conventional designs.

It is concluded that ;

(1) Expansion of bandwidth of axial ratio

Extremely wideband axis ratio was first realized with 10 times wide bandwidth compared to conventional plane antennas.

(2) Miniaturization of side of array by enhanced gain

The directive gain of this array was 18.8 (dB) which is 2.7 (dB) approximately better than the gain without the grounded square collar.

It shows the needed number of (ex. 32) antennas of an array is reduced to half (ex. 16) of conventional design. This contributes miniaturize remarkably the dimension of array.

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