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

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Abstract: - This paper presents a novel configuration of circular polarization array with 64 unit antennas. A novel configurations of a single antenna is presented first. Then a 4-antenna array is given based on orthogonal arrangement and smoothed routing wire for feeding. Then, 64-antenna array is given by the above 4-antenna and 16-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 axial ratio and practically enough high gain were first realized in this paper. These characteristics were realized by the innovative technologies found by the authors. And the result of this study was found to be introduced into practical measuring system for detection of position of liquid surface in LNG and oil tankers.

Key-Words: - Wideband circular polarization antenna, orthogonal arrangement, smoothed routing wire for feeding, grounded square collar at peripheral, elimination of cross-sectional radiation.

1 Introduction

Compact radar antenna is designed by multiple half wavelength resonator antennas on a dielectric substrate. Conventionally stripline antenna has been realized with linear polarization [1, 2].

Recently, circular polarization microwave antennas are expected for practical applications because of much information compared to that of linear polarization.

x and *y* axes resonances are needed for circular polarization on a single stripline resonator. For this purpose, a single slot or a pair of slots are made on the centre or peripheral parts of a square or a circular disc of central conductor of the striplines.

The circular polarization gain-bandwidth of a unit or array antennas are not wide enough to cover expected microwave bandwidth.

Microwave principle and effective structures have been studied by the authors to provide antenna and arrays with high values of gain and bandwidth [3-11].

Novel principle and effective structure is presented in this paper for 64-antenna array composed of novel ideas by the authors.

2 Single Antenna

2.1 Single antenna composed of triplate stripline resonator

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.

2.2 Electric operation

The resonance of each unit antenna is composed of main element ***a***, reactance element ***b***, and ground plate ***g*** as shown in Fig. 1. ***b*** is a round disc truncated lineally at the both sides as shown in Fig. 2. Two resonance modes are given by ***a*** along *x* and *y* axes.

Reactance element ***b*** works as a reactive tuning of resonance, and simultaneously as a transmitter of microwave along *z* axis.

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***.

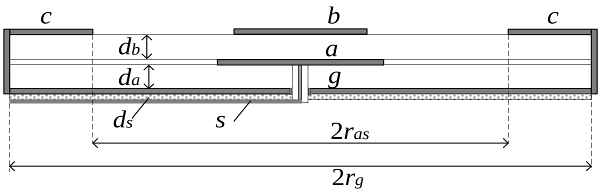

Fig.1 Cross setional view of the proposed antenna.
a : feed element, *b*: reactance element,
g : ground plate, *c* : grounded collar.

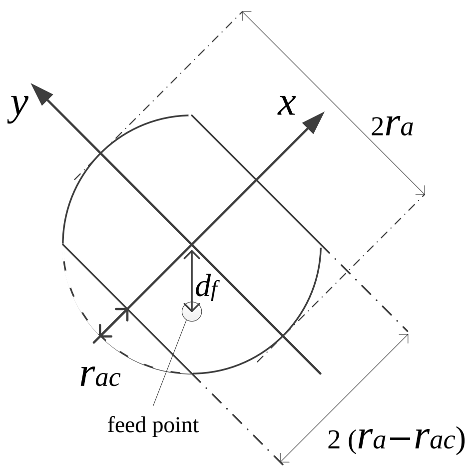

Fig. 2 Main element *a* with feeding.
df: Feeding point.

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 Configuration of 4 antenna array

Four-antenna array is composed by orthogonal arrangement. Microwave power is fed by smoothed routing wires 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 direction left-handed circulation. d_f shows the position of feeding point at each antenna.

The diameter of the ground plate 2*rg* 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. 3. This scheme forms a parallel composition of routing wire.

The condition of 90 degree phase difference are given between right hand elements *a*1 vs *a*4, and the left hand elements *a*3 vs *a*2. At the connection of the right and the left elements, 180 degree and 90 degree phase delay are provided by corresponding line lengths.

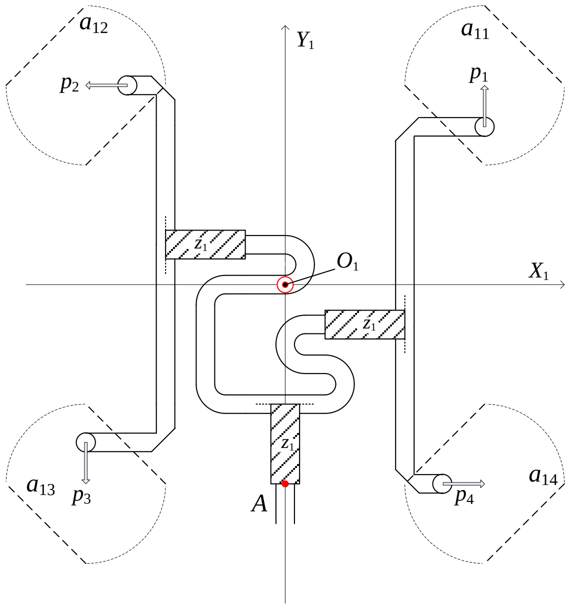

Fig. 3 Smoothed routing wire for a 4-antenna a_{11} ~ a_{14}, and p_1 ~ p_4 are feeding Poynting vectors at the first quadrant. O is the centre of the plane X_1-Y_1. A is the input point of feeding. z_1 and z_0 are characteristics impedances of routing wires.

4 64-Antenna Array

4.1 Spatial arrangement

64-antenna array is composed of 16-antenna array, which are arrange at each of four quadrants. The Cartesian system x- y – z is used. The z axis is vertical to the page and frontward.

This array is composed on x – y plane, and microwave radiates along z axis. The top view of 64-antenna array is shown in Fig. 4. The composition of the feeding routing wire on x – y plane is shown in Fig. 6. Points A_0, B_0, C_0, D_0 stand for the microwave signal input points of each 16-antenna array.

The direction of each 16-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_0, B_0, C_0, D_0 are delayed 90 degree.

By the above operations, the phase differences are cancelled, and it provides synchronized circular polarization waves.

4.2 Grounded square collar

The peripheral of the array is covered by a square collar as shown in Fig. 4. This collar composes a quarter wavelength line with short termination. Cross-sectional microwave radiation is eliminated by this collar. This collar is designed to match the impedance of cross-sectional radiation from inside the array. 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.

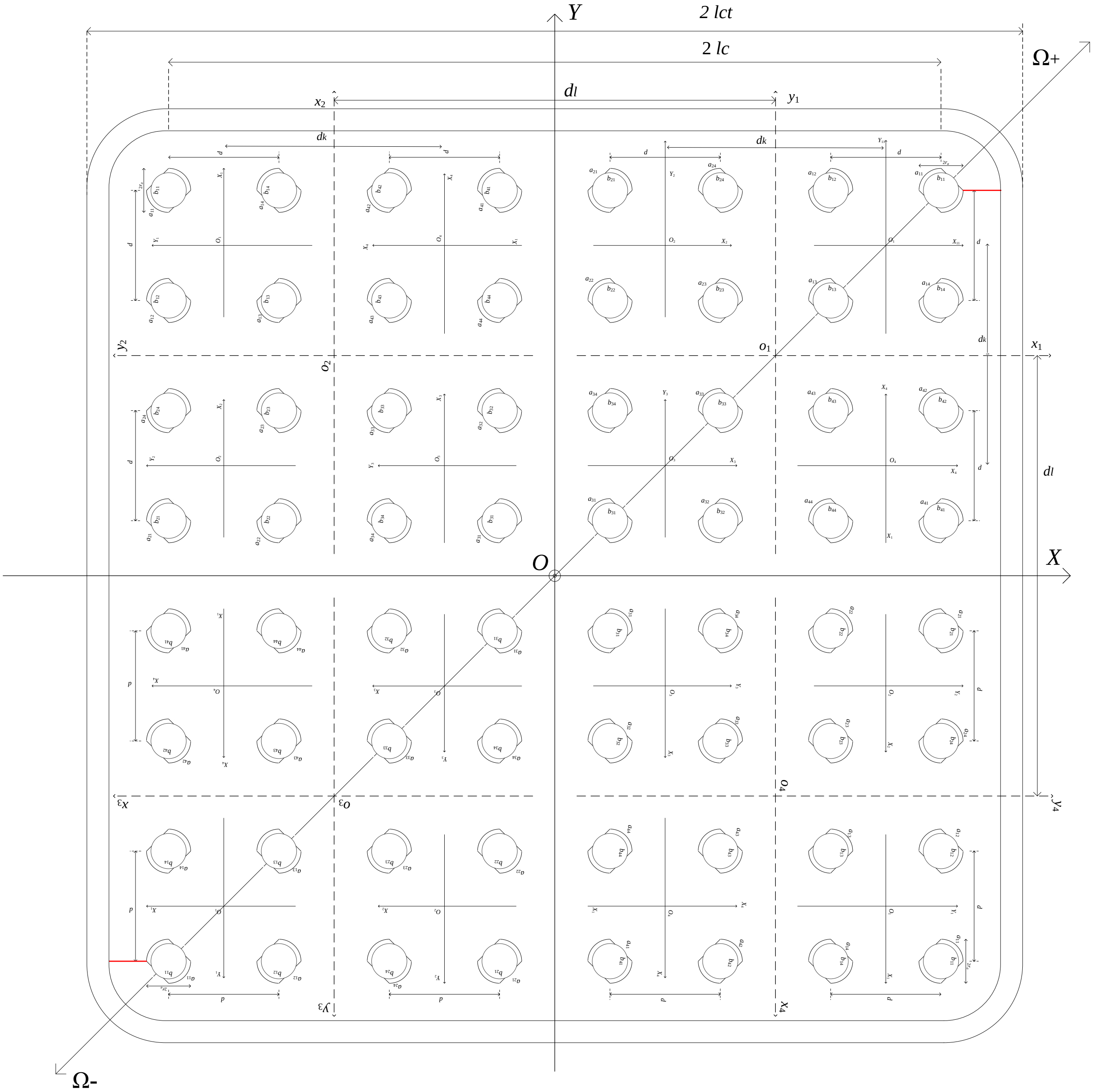

Fig. 4 Top view of 64- antenna array with grounded square collar.

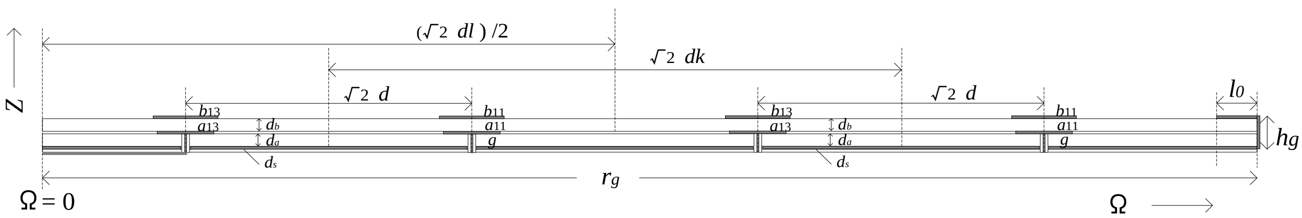

Fig. 5 Cross-sectional view of 64- antenna array on **Ω** - *Z* plane (refer to Fig. 1.)

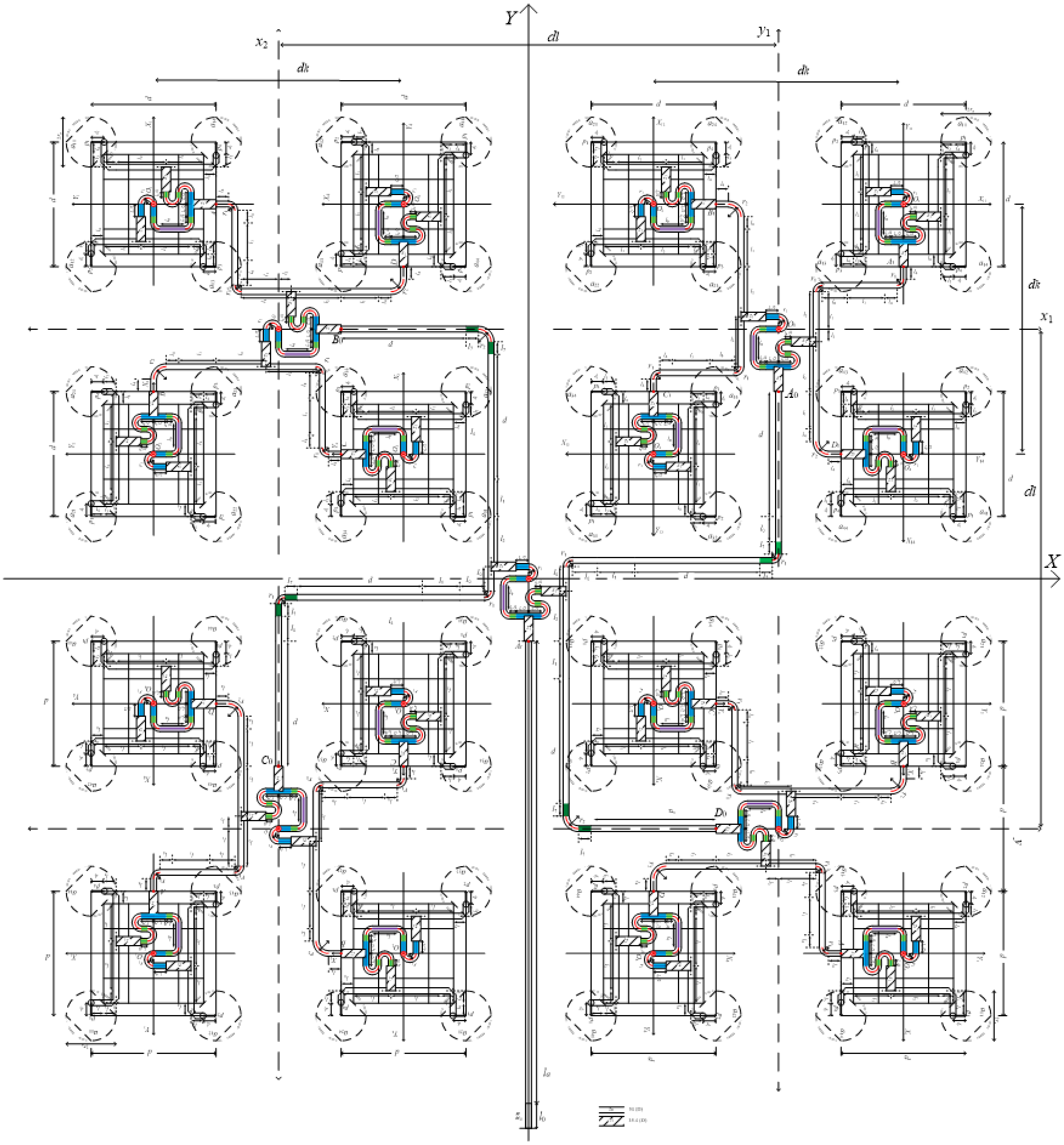

Fig. 6 Feeding Routing wire for 64-antenna array.
The 16-antenna array is allocated in each quadrant with right hand turning 90 degrees.

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. 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 bandwidth of return loss 10 (dB) is 2 (GHz) or more.

(2) Directive gain

The frequency characteristics of directive gain is obtained. The maximum gain was 24 (dB) or more.

(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.

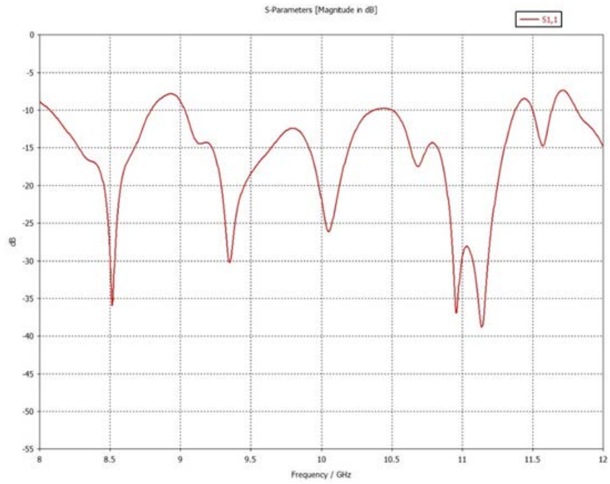

Fig. 7 Return loss (dB).

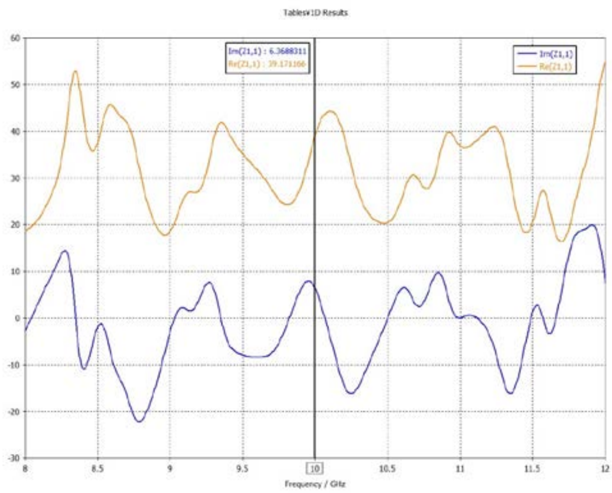

Fig. 8 Input impedance (Ω).
upper lines : real part
lower lines: imaginal part

(4) Axial ratio

The frequency characteristics of axial ratio is shown in Fig. 9. The axial ratio of circular polarization is smaller than 1.5 (dB) between 8.5 ~ 12 (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. 10 and 11. The side lobe level was −12.8 (dB) from the main lobe. It means sharp beam of radiation was given. It was found that the directive gain of this array was 24 (dB) which is 2.5 (dB) approximately better than the gain without the grounded square collar.

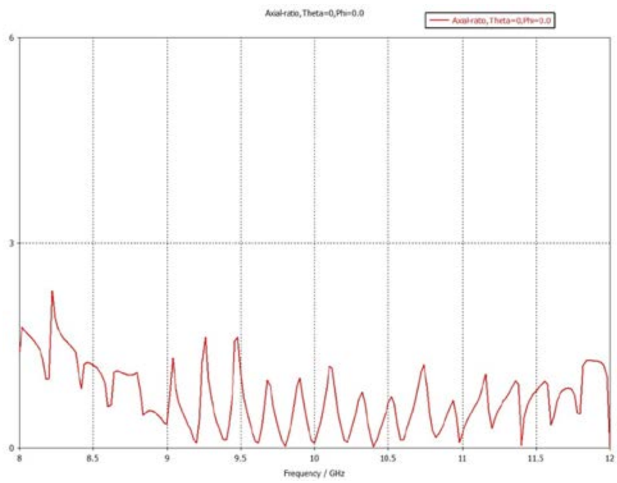

Fig. 9 Axial ratio (dB).

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 64-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.

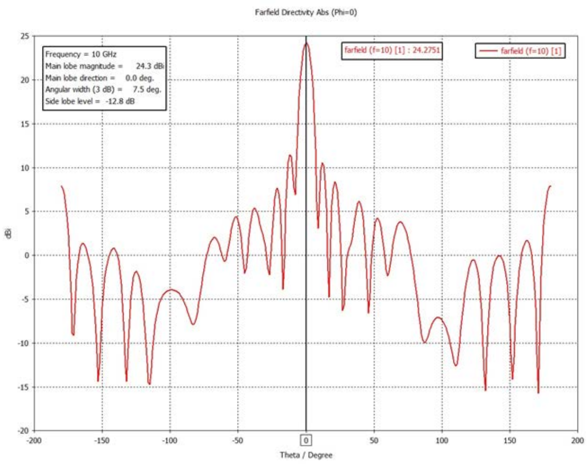

Fig. 10 Farfield directivity (dBi). φ = 0°.

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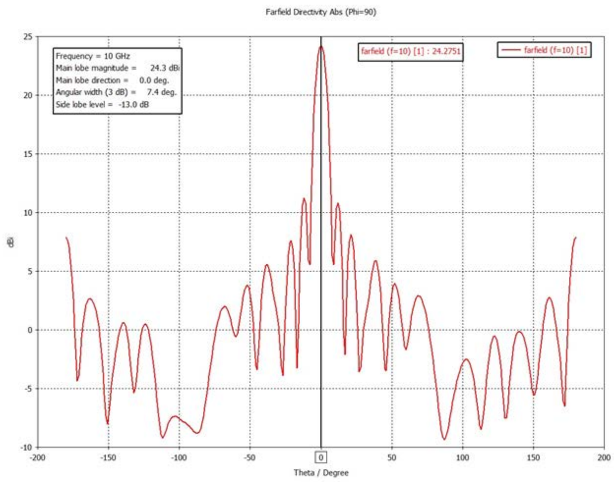

Fig. 11 Farfield directivity (dBi). φ = 90°.

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