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

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

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

1 Introduction

This paper describes a novel configuration of circular polarization array antenna applied to microwave level gauge in oil tanks. This technology is expected to be applied to navigation system in flying machines.

Conventionally orthogonal (*x*-*y*) linear polarization array antennas were provided at C, S, and X-band[1].

Recently circular polarization microwave antennas are studied and used in remote sensing of airplanes for resource and environmental sensing and conservations at C- and S-bands.

Circular polarization antennas at X-band were relatively narrowband as 2.2 ~ 2.4 % [1], and recently a wider bandwidth was obtained [2].

This paper provides novel configuration of an unit antenna and a four-antenna-array to provide wideband characteristics of axis ratio for circular polarization applied to the X-band.

2 Wideband Plane Antenna with Three Elements

2.1 Configuration of Yagi-Uda antenna

The configuration of the Yagi-Uda antenna[3] is shown in Fig. 1. This antenna is composed of three antenna elements, which are (***a***) main element with feed, (***b***) guide, and (***g***) reflector. l_a, l_b, and l_c are lengths of elements (***a***), (***b***), (***g***), and d_a, d_b are the distances between ***a*** – ***b*** and ***a*** – ***c*** respectively.

If an unfed antenna element is set close to the main antenna element with feed, it can operate as a reflector or a guide depending on phase of current on the unfed element.

The phase of the current depends on the distance between the unfed element and the main feed element. Where, the diameter of the rod of element is enough thin compared to the distance.

The antenna gain and the bandwidth are effectively enhanced by the configuration.

2.2 Configuration of the proposed plane 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. 2 and 3.

In Fig. 2, the diameters of feed- (***a***), reactance-elements (***b***), and ground plate (***g***) are $2r_a$, $2r_b$, and $2r_g$ respectively. In Fig. 3, 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. 4, 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. 4, 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. 2. 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.

The circular polarization characteristics of a single antenna is referred to another paper[4] .

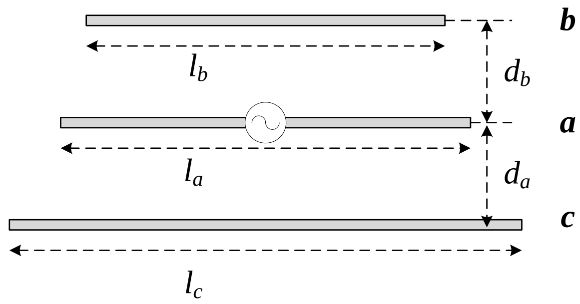

Fig. 1. Yagi-Uda antenna[4].
a : main element with feed
b : guide
c: reflector

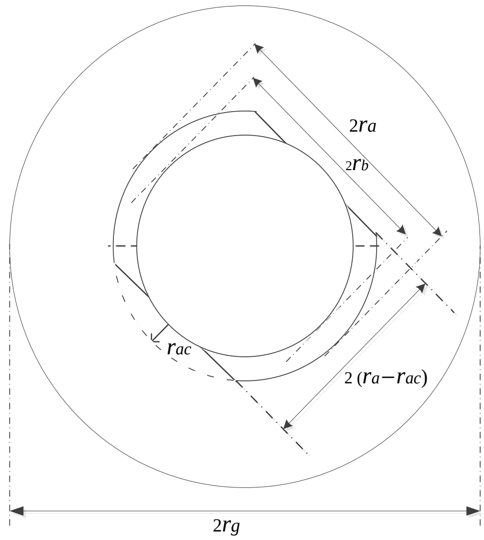

Fig. 2 Overhead view of the proposed antenna. The dimension of reactance element is included.

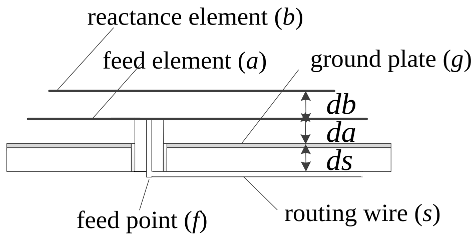

Fig. 3 Cross-sectional view of the proposed antenna.

2.3 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 ;

$$f_L < f_M < f_H \quad (1)$$

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.

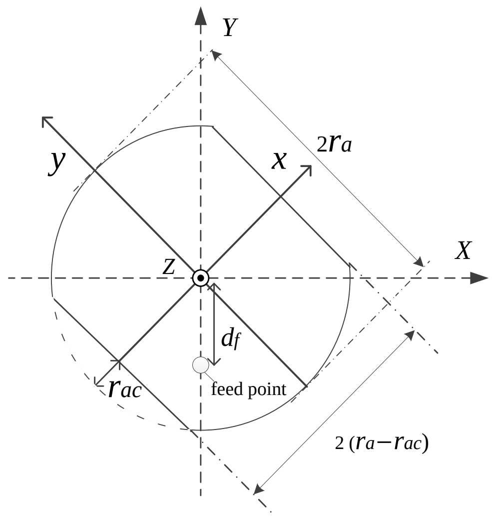

Fig. 4 Dimension of feeding element.

3 Array Antenna with Four Plane Antennas

3.1 Configuration of the proposed array antenna

An array antenna is shown in Fig. 5. Four unit 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 unit 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 Fig. 5. 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.

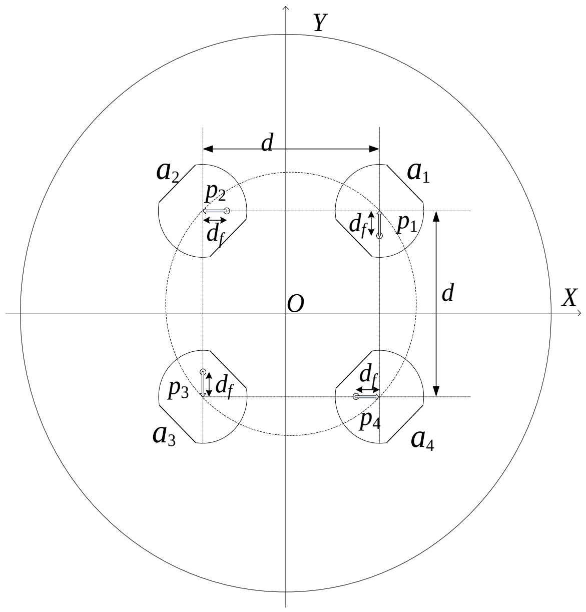

Fig. 5 Configuration of plane array antenna. Reactance elements (patches) and dielectric substrate are abbreviated.

3.2 Routing wire configuration

The design of routing wires for feeding to four antennas is shown in Fig. 6. 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.

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. 7~10 based on 3D computer simulation with CST Studio Suite.

(1) Return loss
The frequency characteristics of return loss is shown in Fig. 7.

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. 8.

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. 9. 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 8.8 to 11.2 GHz. It proves that larger size array antenna becomes practical by this paper.

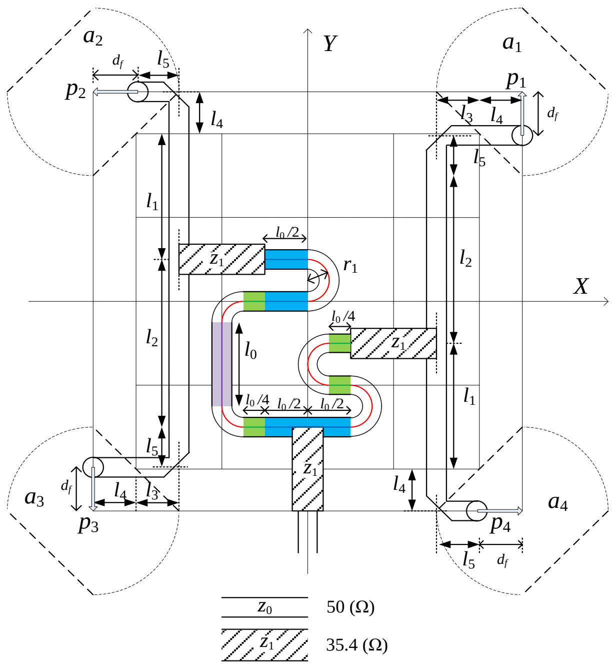

Fig. 6 Routing wire pattern for the proposed array antenna with 4 unit antenns.

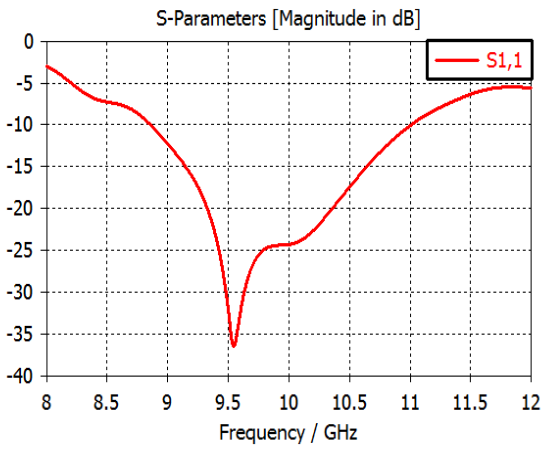

Fig. 7 Frequency characteristics of return loss.

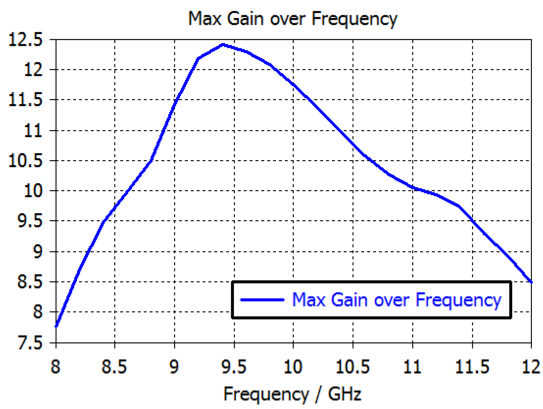

Fig. 8 Frequency characteristics of directive gain.

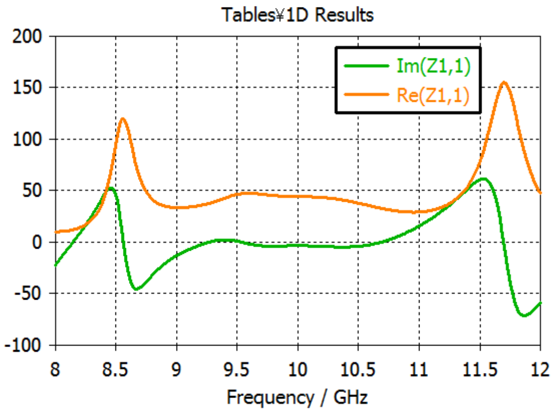

Fig. 9 Frequency characteristics of input impedance.
Upper line: the real part of impedance.
Below line: the real part of impedance.

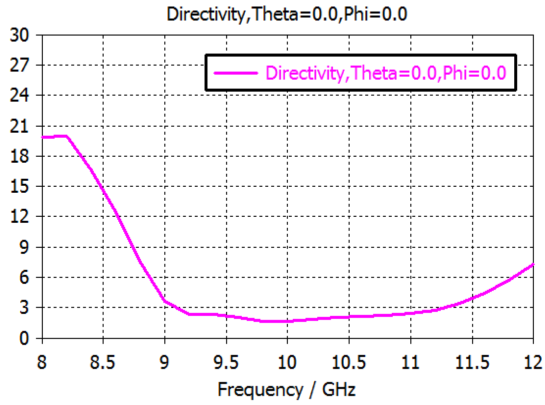

Fig. 10 Frequency characteristics of axis ratio of circular polarization.

(4) Axis ratio

The frequency characteristics of axis ratio is shown in Fig. 10.

The axis ratio of circular polarization is smaller than 3 dB between 9.1 ~ 11.3 GHz.
The axis ratio shows flat and wideband characteristics of circular polarization at X band.

5 Conclusion

A novel circular polarization antennas and an array antenna are presented in this paper. Circular polarization scheme was composed by smooth resonator in shape of inner conductor of plane antenna. This provides wideband resonator without multiple higher modes. Using this unit antenna, an effective structure was presented for a novel array antenna. A novel design is also presented for an effective structure of the routing wire to feed antennas in the array antenna.

Based on the scheme described above, a wideband array antenna was realized for circular polarization in X-band.

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