Characteristics of a Circular Polarization Plane Antenna with Grounded Cylindrical Collar

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Abstract: -This paper presents that a novel structure is given for elimination of cross-sectional radiation. Effective ways have not been given conventionally for reduction of cross-sectional radiation. A plane antenna is made of stripline antenna with feed- and reactance-elements, and the ground plate for circular polarization plane antenna. A quarter wavelength stripline with short circuit termination is provided around an antenna. This element provides capability of elimination of cross-sectional radiation from the antenna. By 3D computer simulation, the directivity is enhanced around 1 dB compared to an original antenna without cylindrical collar. It shows that about 1/3 of total energy radiation is transferred from cross-sectional directions to z axis direction.

Key-Words: - Circular polarization, layered plane antenna, wideband characteristics, directive gain.

1 Introduction

Recently microwave measurement system is concerned for remote sensing of landscape, weather observation, and broad casting receivers. For this system, linear polarization has been used for the purpose. This system causes unreliability in sensing effects because of nonstable reception of reflected signals from moving targets.

Circular polarization have been respected on the capability of robustness for interference among undesired multipath components. In place of conventional waveguide antenna system, plane antennas are respected for the small size and economic advantages. Its volume and size are effective small, but plane antennas are not capable of supressing cross-sectional radiation because of plane structure. Furthermore, by conventional design, antennas are produced with truncated metal resonator and substrates. Cross-sectional radiation are not effectively supressed, and as the results, the total characteristics are not stable because of interference by existence truncation.

This paper presents a circular polarization antenna with newly proposed ground plate. This configuration provides enhancement of the gain and directivity of the plane antenna.

2 Configuration of the Antenna with the Folded Ground Extension

2.1 Configuration of the proposed antenna

The proposed 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. 1 and 2.

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 .

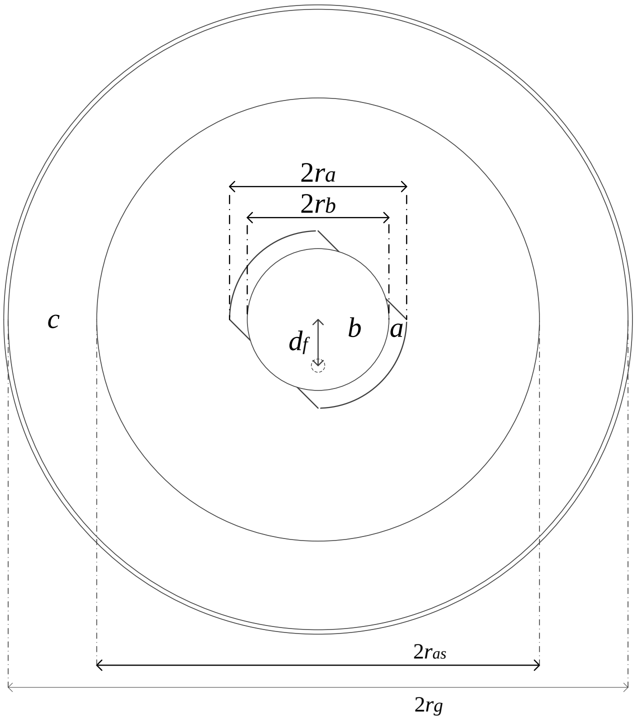

Fig.1 Configuration of proposed antenna with ground extension.

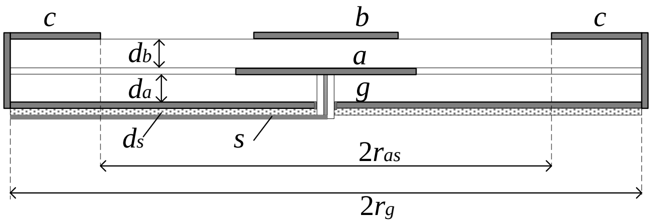

Fig.2 Cross setional view of the proposed antenna.
a : feed element, *b* : reactance element, *g* : ground plate, *c* : cylindrical collar.

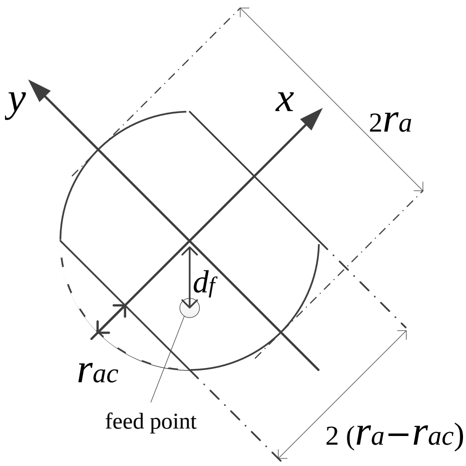

Fig. 3 Main element *a* with feeding.
df: Feeding point.

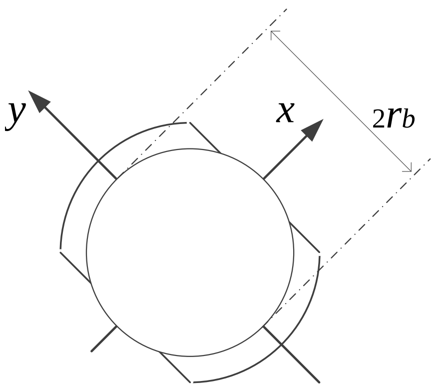

Fig. 4 Overview of a unit antenna of main and reactance elements (*a* and *b*) .

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 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***.

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 Characteristics of Antennas with/without Folded Ground Plate

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. 5~8 based on 3D computer simulation with CST Studio Suite.

The characteristics of two antennas are shown without (in the left side) and with the proposed folded ground plate (in the right side).

(1) Gain vs frequency
The frequency characteristics of power gain is shown in Fig. 5 and 6. It is found that the gain is enhanced 1.3 dB than the left.

(2) Axial ratio
The frequency characteristics of axial ratio is shown in Fig. 7 and 8. Where, axial ratio is defined by the ratio in dB of electric field strength along *x* and *y* axes. The bandwidth of 0.7 GHz (7%) was obtained. Almost they are same between the left and the right.

(3) Directivity
The far field radiation pattern of directivity at φ = 0 (rad) is given by polar coordinate in Fig. 9 and 10.

The maximum gain of the main robe is enhanced 1.5 dB than the left.

The side robe levels are reduced 4.3 dB than the left.

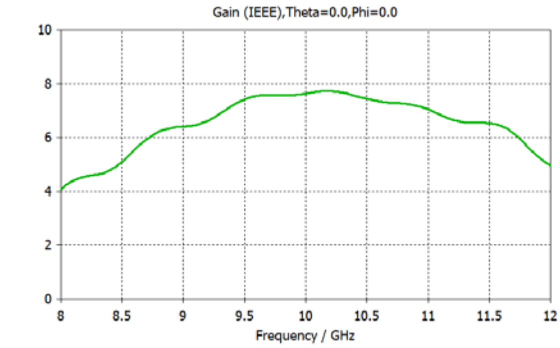

Fig. 5 Gain vs Frequency without ground extension.

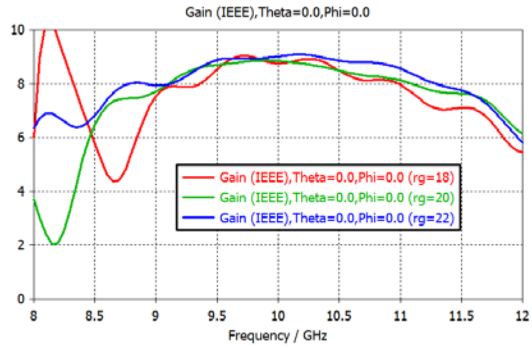

Fig. 6 Gain vs Frequency with the proposed folded ground extension.

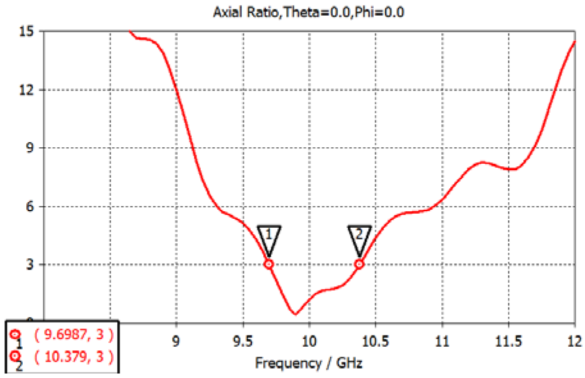

Fig. 7 Axial ratio without ground extension.

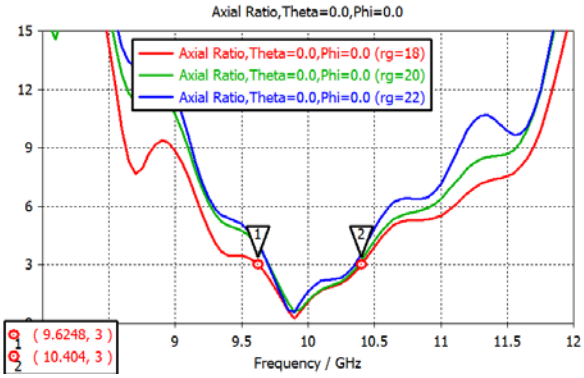

Fig. 8 Axial ratio with the proposed folded ground extension.

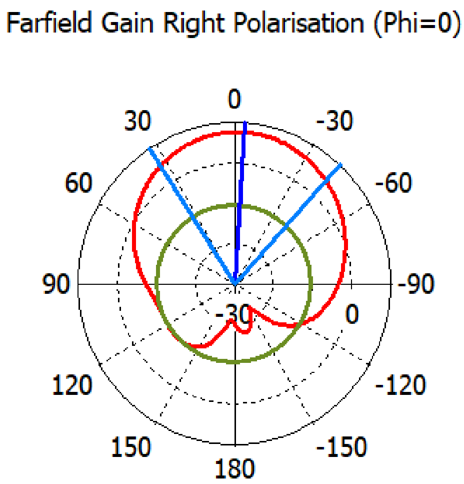

Fig. 9 Far field radiation pattern of directivity without ground extension.

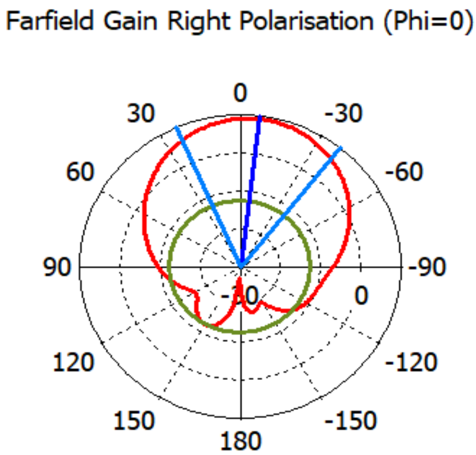

Fig. 10 Far field radiation pattern of directivity with the proposed ground extension.

4 Contribution of Studies by the Authors

4.1 Evaluation of conventional schemes and technologies

Conventional theories and technologies of circular polarization antennas were studied and compared to that of the authors.

(1) Evaluation of conventional schemes and structure are studied for plane resonators with multiple modes. Where, lower and higher frequency resonances are needed to define lower and higher frequencies of bands to provide effective bandwidth for circular polarization.
(2) Conventional schemes of resonators were evaluated by the authors for degeneration of resonances, which defines the effective bandwidth of circular polarization based on return loss, input point impedance, axis ratio, and gain and directivity. As the result of the studies, the bandwidth meeting the circular polarization condition was found about 1 ~ 2 % of center frequency.

4.2 Schemes and technologies by the authors

Novel technologies have been studied by the authors;
The characteristics needed for our target systems are to cover about 10 % of the center frequency at X – band or so.
(1) A novel resonators of degenerated resonators for circular polarization antenna was first given using circular disk with linear truncation at both diagonal sides.
(2) Orthogonal arrangement for array with four antennas were given for wideband axial ratio and high gain.
(3) Novel design of routing wire for feeding was given by smoothed lines (-S-type) in place of rapid bending lines (T-type).
(4) Novel design of structures of distributing antennas on a plane of array antenna was given in this paper. A microwave eliminator was provided to the peripheral of stripline antennas.

5 Conclusion

A novel configuration of the extended ground plate folded at the top of antenna was given in this paper for enhancement of gain and directivity. A grounded cylindrical collar is provided at the outside of the plane antenna. This collar provides reverse current against current of a reactance element. The radiated filed by these current cancel with each other. As the result, farfield radiation is reduced effectively outside of the cylindrical space.

By 3D computer simulation, it was proved that wideband circular polarization antenna is realized by the proposed structure with three-element plane antenna and a quarter wavelength stripline with short circuit termination.

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