Circular Polarization Array Antenna with Triplate Stripline Elliptic Resonator Antennas

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Abstract: - This paper presents a plane antenna and array for X-band circular polarization. The novel factors of this development are elliptic resonator antenna and Glass-Epoxy substrates. High efficiency in resonance and radiation of microwave energy is expected by elliptic resonators. Easy process in fabrication is expected by Glass-Epoxy substrate. Elliptic ratios of feed- and reactance-elements are chosen independently each other. The dielectric constant \( \varepsilon_r \) and \( \tan \delta \) are 4.6 and 0.010 respectively. Enough bandwidth of axial ratio of circular polarization and directive gain are confirmed to be 15% of central frequency and 10 dB respectively for antenna array.

Key-Words: - Circular polarization plane antenna, S-type routing wire, Reduction of horizontal radiation, Grounded square collar


1 Introduction

Stripline array antenna provides remote sensing systems with compact and inexpensive antennas. The authors are interested in three-layered substrates to compose wideband circular polarization plane antenna. Low loss stripline antennas have been designed using fluorine resin (Teflon) substrate conventionally. The permittivity (relative dielectric constant \( \varepsilon_r \)) is small as 2.17 at 10 GHz X-band, so the parameter values (practical dimensions) are not needed to be strict. Metallization and multilayered substrates of the Teflon require much processing cost and times.

In this development, two novel factors are considered. The first one is the structure of stripline resonators. Triplate stripline configuration is composed by feed- and reactance-elements on the ground plate. This concept was given by the structure of Yagi-Uda antenna[1]. This antenna is composed of three elements. Feed- and guide/radiation of microwave energy. Another element is assigned by reflector of microwave energy. Feed- and reactance-elements corresponds to feed- and guide/radiation elements. Another is assigned as the ground element.

For microwave circular polarization, degeneration of two resonant modes must be realized in a resonator.

Square and circular disc conductors with truncation are used degeneration in conventional antennas [2, 3].

In this paper, elliptic feed-and reactance-elements are proposed. Low and high frequency resonances are assigned to meet the required condition of degeneration.

The second factor of this development is dielectric material of Glass-Epoxy substrates. It is expected to provide easy process in fabrication. The relative dielectric constant \( \varepsilon_r \) is high 4.6, and \( \tan \delta \) 0.01. It is estimated that design rule is too strict compared to that of the antenna made of Teflon substrate.
2 Unit Antenna

Figure 1 gives a triplate stripline resonator antenna composed of feed- and reactance-elements \( a \) and \( b \), and the ground plate \( g \). The substrate \( s \) under the ground plate provides feeding routing wire for the antenna. Feed element \( a \) is fed with vertical probe through substrate \( s \) under the ground plate. Collar \( c \) shows a \( \lambda g/4 \) line with short termination for suppression of horizontal radiation.

Figure 2 shows elliptic feed- and reactance-elements. They are defined by individual ellipses. \( 2ra1 \), \( 2ra2 \) are major and minor axes of ellipse of feed-element, which yields \( x \) and \( y \) axis-components for a rotating polarization vector.

3 Four-Antenna Array

3.1 Orthogonal arrangement of four antennas

An orthogonal arrangement of four-antenna array is given in Fig. 3. Each antenna is settled in the space of four quadrants in the coordinate \((X, Y)\).

The rotational directions of the four antennas are set in the rotational symmetry with 90 degree difference in each other.

Considering the clockwise circular polarization, each antenna in spaces advances 90 degree electrically.

3.2 Compensation of the special and temporal phases

Compensation of the special and temporal phases is needed to provide synchronous radiation among four antennas.

Considering the relations of the electrically advanced phase, these antennas should be fed with delay of 90 degree electrically to keep the condition of synchronous rotation field by four antennas based on.

3.3 Parallel feeding

Orthogonal arrangement of antenna array and parallel feeding have been designed by Y. Takizawa and A. Fukasawa.

One of the pair antenna is given by two antennas in the 1st and the 4th quadrants. Another pair antennas is given by two antennas in the 2nd and the 3rd quadrants.
3.4 Design of 4-antenna array

(1) Design target
The central frequency and the bandwidth are given as follows;
Central frequency \( f_0 = 10\text{GHz} \)
Bandwidth \( W = 1 \text{GHz} \)

Glass-epoxy substrates are used, and the dimensions of the three-layer substrates are;
Dielectric substrate \( \varepsilon_r = 4.6, \tan \delta = 0.010 \)

(2) Antenna Structure
Triplate stripline is composed as;
Thickness \( (da, db, ds) = (1.0, 1.0, 0.4) \)
(3) Array structure
Antenna spacing $d = 20$ (mm)
Array size including square collar $2l_g = 42$ (mm)

(4) Antenna size and feed point

<table>
<thead>
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<td>reactance element</td>
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<td>$rb_2/rb_1$</td>
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<td>ellipticity $rb_2/rb_1$</td>
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</table>

Table 1 Parameter values antenna dimension.

4 Characteristics of 4-Antenna Array

The evaluation was given by 3D computer simulation CST in the environment constructed by C.E. Santosa, Chiba University. The characteristics of the array are evaluated by return loss, input impedance real and imaginary, axial ratio, and directive gain shown in Fig. 4, 5, 6, 7, and 8. Wideband axial ratio and high directive gain were confirmed by this configuration and design.

Four different conditions in Fig. 4-7 correspond to different position of collars (quarter wavelength line termination at the peripheral of array) $lx = 1.1$ to $1.6$ (mm). The best data was given by the blue lines $lx = 1.1$ in Fig. 4-7, and red line in Fig. 8.
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