Waveguide Slot Array In-Motion Antenna for Receiving both RHCP and LHCP using Single Layer Polarizer

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Abstract — In motion slot array antenna for receiving satellite broadcasting is presented. To reduce the loss of feed line and to reduce the coupling between the slots, we use the waveguide feeding network and the circular groove. By using two cross-type polarizers, which are implemented on a single layer film, the proposed antenna can receive RHCP or LHCP by mechanical switching system. The gains of 4x8 and 8x16 slot array antennas are 27.5dB, 31.5dB respectively. Also, in satellite broadcasting band of 11.75~12.75GHz, the axial ratio is smaller than 5dB.

Index Terms — Waveguide Feed Network, LHCP polarizer, RHCP polarizer, Slot Array Antenna

I. INTRODUCTION

Most of the slot antennas receive a horizontal or a vertical linear polarization. But, these antennas can receive a circular polarization by using a polarizer. The general structure of polarizer is a dipole or a meander-line type [1~4]. A dipole polarizer has a narrow axial bandwidth. A meander-line type has a wide axial bandwidth but has to use a multilayer film. Also, these polarizers can receive only RHCP or LHCP.

In this paper, we propose a cross-type polarizer. By using two cross-type polarizers, which are etched on a single layer film, the proposed antenna can receive both RHCP and LHCP by mechanical switching system. A single layer film is moved to the left or right direction by motor. The axial bandwidth of proposed antenna is relatively wider than the existing antenna using a dipole polarizer in the satellite broadcasting band of 11.7~12.75GHz. In order to reduce the feed loss, the waveguide feed networks are used.

Fig.1 shows the structure of the proposed antenna system with two cross-type polarizers. In a top layer of slot antenna, there are the slots and the circular grooves to reduce the coupling between adjacent the slots and to improve the directivity of a proposed antenna. In a middle layer of slot antenna, there are the sub cavities below slots to simplify the feed network systems. In a bottom layer, there are the power dividers and the converters for a change of wave direction losslessly.

II. ANALYSIS AND DESIGN FOR POLARIZER

2.1 Theoretical background

As placing the parasitic element such as a dipole above a slot with a certain distance, the linear polarization radiated from a slot is converted to the circular polarization [5]. In order to explain briefly the principle of polarizer, suppose that a slot and a dipole are placed above infinite conducting screen with a certain distance such as Fig.2 [6]. Then E-field ($E_n$) radiated from a slot is expressed as the
following equation (1). And $E_s$ is expressed to the summation of RHCP and LHCP

$$E_s = -x \sin \theta + y \cos \theta$$

$$= \frac{j}{\sqrt{2}} \left[ \left( \frac{1}{\sqrt{2}} - j \frac{1}{\sqrt{2}} \right) (\cos \theta + j \sin \theta) \right]
\left( \frac{1}{\sqrt{2}} + j \frac{1}{\sqrt{2}} \right) (\cos \theta - j \sin \theta) \right]
= j \frac{C_{RE} e^{j \theta} - C_{LE} e^{-j \theta}}{\sqrt{2}}$$

(1)

In similar manner, E-field ($E_D$) radiated from a dipole is expressed as following equation (2)

$$E_D = (a_x \cos \varphi + a_y \sin \varphi)(2 j \sin \phi) A_D$$

$$= \sqrt{2} j A_D \sin \phi (C_{RE} e^{j \varphi} + C_{LE} e^{-j \varphi})$$

$A_D$ : complex amplitude of the induced current on the dipole

$A_D = a_D (l, h) \sin(\varphi - \theta)$ (l=dipole length)

In far-field, by adding equation (1), (2), E-field is sorted to total RHCP and LHCP such as following equations (3), (4)

$$E_{\text{RHCP}}^\text{Total} = j \frac{e^{j \theta}}{\sqrt{2}} + \sqrt{2} j A_D \sin k h e^{j \varphi}$$

(3)

$$E_{\text{LHCP}}^\text{Total} = -j \frac{e^{j \theta}}{\sqrt{2}} + \sqrt{2} j A_D \sin k h e^{-j \varphi}$$

(4)

From a equation (3), (4), only a circular polarization of LHCP or RHCP can be obtained by adjusting the length of dipole (l), the distance between a dipole and a slot (h), the angle between a slot and a dipole ($\varphi - \theta$)

In this paper, by adjusting other parameters and fixing $\varphi - \theta = 45^\circ$, the axial ratio and the impedance bandwidth of the antenna are optimized using 3D simulator, MWS (Micro Wave Studio)

2.2 Design of cross type-polarizer

Fig.3 shows the structure of the sub cavity as a part of the proposed antenna. As seeing the Fig.3, there are many parameters. In these parameters, the length of polarizer (pl) and the distance between a slot and a polarizer (gh) are the dominant parameters affecting the impedance bandwidth and axial ratio of the proposed antenna.

As varying the value of pl, gh, we obtain the axial ratio chart. Fig.4 shows an example of the chart to determine the optimum parameters of the polarizer. From this figure, if $10.6 \geq pl \geq 10.2$, $3.9 \geq gh \geq 3.4$, the axial ratio is below 1dB. On the basis of these values, by adjusting the other parameters, the impedance bandwidth and axial ratio bandwidth are optimized by using 3D simulator.

Table.1 shows the optimized parameter values.

The proposed antenna in Fig.3 can only receive LHCP. However, if a polarizer for receiving RHCP is placed between the circular grooves, the proposed antenna can receive both RHCP and LHCP simultaneously as a film is moved to the right or left direction by a motor such as Fig.5.
Fig.6 shows the optimized return loss and axial ratio using simulator. When RHCP and LHCP cross-type polarizers are together, the return loss and axial ratio deteriorate. Because the coupling between two polarizers occurs.

Table.1 Optimized parameter values for one sub cavity

<table>
<thead>
<tr>
<th>Sub cavity</th>
<th>Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>cw=ch</td>
<td>0.943 λ</td>
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<tr>
<td>ch</td>
<td>0.207 λ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polarizer</th>
<th>Circular groove</th>
</tr>
</thead>
<tbody>
<tr>
<td>pl</td>
<td>0.427 λ</td>
</tr>
<tr>
<td>pw</td>
<td>0.077 λ</td>
</tr>
<tr>
<td>ml</td>
<td>0.163 λ</td>
</tr>
<tr>
<td>gh</td>
<td>0.264 λ</td>
</tr>
</tbody>
</table>

III. MEASUREMENT

3.1 RHCP, RHCP+LHCP antenna (4X8)

Fig.7 shows the manufactured antenna. WR75 to SAM adaptor is connected to the proposed antenna. Fig.8 and Fig.9 show the measured return loss, axial ratio, and radiation pattern. From these figures, 10dB impedance bandwidth satisfies the satellite broadcasting band. And 3dB axial ratio bandwidth is 5% (11.8~12.4GHz). Like the simulation results, the axial ratio of the cross-type RHCP and LHCP polarizers together deteriorate due to the coupling between the polarizers. On the average, the peak gain of proposed antenna is 27.5dB.
3.2 RHCP+LHCP antenna (8X16)

Fig. 10 shows the antenna whose radiation element number is 8X16. The gain of this antenna is indirectly measured using the Friis transmission equation [7]. After adapting a LNB whose gain is 55dB, C/N is measured in outdoor, Korea with fine day. Transmitting artificial satellite is KORSAT3

\[
C / N = EIRP \left( \frac{\lambda}{4\pi R} \right)^2 \frac{G_A G_{LNA}}{T_e} \frac{1}{k_e}
\]

\[
= EIRP \left( \frac{\lambda}{4\pi R} \right)^2 \frac{G_A G_{LNA}}{N} \frac{B^2}{N}
\]

(\(\because N_0 = kT_e B, N = N_0 B\) )

where, \(G_A\) = Antenna gain, \(G_{LNA}\) = LNB gain
\(k\) : Boltzmann's costant, \(B\) = Bandwidth
\(N\) = Noise power, \(N_0\) = Noise power spectral density,
\(T_e\) = Equivalent noise temperature

Here, EIRP=55dBW, \(R=35789km\), \(f=12.53GHz\), \(B=191MHz\), \(G_{LNA} =55dB\), Received noise power=57.5dB, Polarization loss=3dB, the other loss=1dB. As substituting these values to the equation (5), the gain of the antenna is 31.5dB

IV. CONCLUSION

In this paper, by using the waveguide feed network and a single layer film, the antenna that has a high gain and can receive both RHCP and LHCP mechanical switching system is proposed. 3dB axial ratio of the proposed antenna is 5% (11.8~12.4GHz). The gains of propose 4X8, 8X16 antenna are 27.5dB, 31.5dB respectively.

V. REFERENCE