Reflection coefficient calculation of a feeder structure in a RLSA

Nam Koo Kang*[1], Seong Cheol Kim[2] and Sang Wook Nam[3]
School of Electrical Engineering
Seoul National University, Seoul, Korea
E-mail : [1]alovme@maxwell.snu.ac.kr, [2]sckim@maxwell.snu.ac.kr, [3]snam@ee.snu.ac.kr

Abstract

RLSA(Radial line slot antenna) is slotted waveguide array antenna which is proposed for the DBS(Direct Broadcast from a Satellite) reception.

Theoretically, it has lower conduction loss and higher effectiveness than the planar antenna using microstrip. DL-RLSA(Double-layered RLSA) uses radially inward travelling wave for the slot excitation in the double-layered radial line. The effectiveness of DL-RLSA is more than 75%(33.0~37dBi), which is two times as high effectiveness as other planar antenna. In spite of that advantage, SL-RLSA(Single-layered RLSA) is more popular because of the complex structure of DL-RLSA. But the radially outward travelling wave of SL-RLSA makes high tapering when the travelling wave approaches the aperture edge. To remove these troublesome thing, a effective feeder structure which has tilting rod is proposed in this paper. To find the optimum height and tilting angle of the feeder, the finite-difference time-domain(FDTD) method is employed. In other words, the simulation parameter of the FDTD algorithm is the dimension of feeder.

Compared with the effectiveness of the conventional rod feeder structure, that of the proposed feeder structure in this paper is enhanced by 5dB.

Indexing Terms : Radial Line Slot Antenna, Direct Broadcast from a Satellite, Tilting Rod

1. Introduction

RLSA(Radial line slot antenna) for the DBS(Direct Broadcast from a Satellite) reception in the 12GHz band is in commercial use in Japan. Its flat shape is so solid and so small compared with the planar antenna using microstrip. Theoretically, it is free of conduction loss and high efficiency is expected in principle. From the satellite signal receivers viewpoint, it is main issue to make the receiving antenna smaller with the same or more efficiency. There is two possible designs of RLSA, which are DL-RLSA(Double-layered radial line slot antenna) and SL-RLSA(Single-layered radial line slot antenna)[1].

In terms of structural simplicity, SL-RLSA is very attractive. However, it utilizes a radially outward traveling wave and the aperture field is intolerably tapered[2]. So the optimization of various factors of SL-RLSA is inevitable. One of them is optimization of feeder structure to sustain the power to the edge.

0-7803-7330-8/02 $17.00 © 2002 IEEE

2. Simulation Geometry

The simple geometry of simulation is described in Figure 1.

Basically, SL-RLSA has the air region of radius 50mm around the feeder and dielectric region from the end of the air region to the edge of the SL-RLSA. But this paper truncates the simulation region at the radius 75mm, that is, the radially length of dielectric region is 25mm. It means that the small reflection at the slot and the reflected wave at the edge of the SL-RLSA leave out of consideration, because those field-distorting factors cannot be improved by the optimization of the feeder structure.

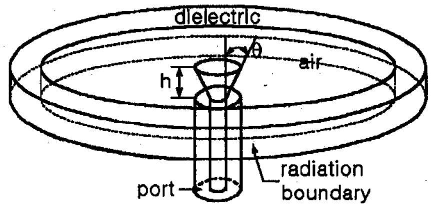

Figure 1. Simulation Geometry

The dimension of coaxial cable follows SMA type standard. and the thickness of SL-RLSA is 7.5mm. And the input port lies at the boundary of the coaxial cable and the SL-RLSA body, namely, at the termination of the coaxial cable. Because the propagation characteristics of the coaxial cable cannot be improved like the field-distorting factors.

2.1. Necessity of Feeder Optimization

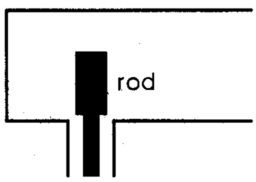

Figure 2. General feeding structure

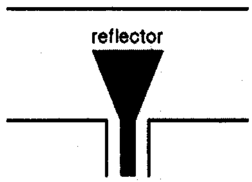

Figure 3. Tilting rod

The input port of coaxial cable and the body of SL-RLSA are perpendicular to each other as the Figure 3. This structure makes a drop in efficiency of power propagation from the coaxial cable to the inner part of the antenna. Generally, the cylindrical rod from the input port to the inner part of waveguide is used at the feeder like Figure 2. In that structure, the return loss of the feeding is about 10dB. Moreover, as mentioned above, the tapering around the propagation edge is so serious.

To get the radial radiation pattern in the antenna body and overcome those structural defects, the feeder optimization like Figure 3 is required.

2.2. Loss Profile of the Tilting Rod

The loss profile around the feeder can be classified into two elements, the diffraction loss of case 1, 2 and the reflection loss of case 3 in the Figure 4.

If the reflector angle increases, the power loss caused by the case 1 increases. The wave from the coaxial cable makes diffraction at the corner of the feeder and the diffracted wave is inserted into the antenna body. However, some part of the diffracted wave which incidents on the reflector with θ larger than 90° is returned to the input port. So increasing reflector angle gives rise to increasing power loss by case 1. And if the reflector angle decreases, the power loss caused by the case 3 increases. Case 3 shows the direct back reflection at the top of the SL-RLSA. Decreasing reflector angle makes the direct back reflection region wide. It leads to the increasing power loss by the case 3. But the power loss of the case 2 is not much affected by the tilting angle of the reflector and the tilting rod dimension is too small to make the diffraction phenomena based on GTD.

Finally, the feeder optimization procedure is a process of harmonizing the diffraction loss of case 1 with the reflection loss of case 3.

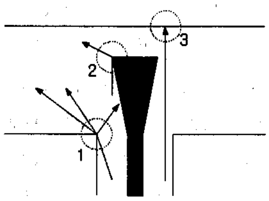

Figure 4. Loss profile

3. Simulation Parameters of Optimization

The principal simulation parameters are the height and tilting angle of the reflector. The range of simulation height is from 3.5mm to 6.5mm at 0.5mm intervals and that of simulation angle is from 10° to 60° at 1° intervals. The rest range is not dealt with. Because the effectiveness of feeder having the dimension beyond the limits of simulation range is so low. Reflector is let perfect conductor and the upper, lower bounds of the SL-RLSA body is assumed perfect conductor, too. Last assumption is that the dielectric constant of the dielectric material out of the air region is 1.5. That is the value made use of when the real SL-RLSA is produced.

4. Numerical Result

Figure 5 shows $|S_{11}|$ by the FDTD simulation. The legend in that figure is the height of reflector. $|S_{11}|$ has the minimum value of 0.16 at the point of 3.5mm height and 19° tilting angle.

At the point of 55° tilting angle, there is no effect of reflector height. There is two reasons of this phenomenon. First, the blocking up the path of case 2 and case 3 in the figure 4. At that angle, the radius of the reflector's top is large enough to block two path. So return loss is determined by the case 1 only. However, return loss of case 1 is mainly affected by the tilting angle. Therefore, all the graphs come together at one point.

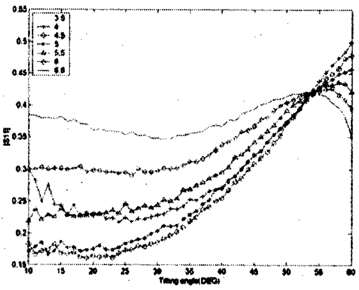

Figure 5. |S11| by FDTD simulation

5. Conclusions

In this paper, the characteristics of a single-layered RLSA is explained and the feeder design for sustaining the input power to the edge of antenna is presented.

From the result of the simulation, S_{11} can be calculated, and the effectiveness of the tilting rod of various dimensions can be identified. Proposed structure shows 15dB return loss. It diminishes insertion loss by the 5dB with respect to the cylindrical rod.

However, there is some distortion of the signal shape. It means that this structure must be improved to maintain the original signal shape.

References

[1] M. Takahashi, J. Takada, M. Ando and N. Goto, "A slot design for uniform aperture field distribution in single-layered radial line slot antennas", *IEEE Trans. Antennas Propagat.*, vol. 39, no. 7, pp. 954-959, 1991.

[2] M. Takahashi, J. Takada, M. Ando and N. Goto, "Characteristics of small-aperture, single-layered, radial-line slot antennal", *IEE Proc. Pt. H*, vol. 139, no. 1, pp. 79-83, 1992.

[3] K. S. Yee, "Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media", *IEEE Trans. Antennas Propagat.*, AP-14, 4, pp. 302-307, 1996.

[4] Kurt L. Shlager and John B. Schneider, "A selective survey of the finite difference time domain literature", *IEEE Antennas and Propagation Magazine*, vol. 37, no. 4, pp. 39-56, 1995.

[5] Dennis M. Sullivan, "Electromagnetic simulation using the fdtd method", IEEE Press Series on RF and Microwave Technology, 2000.

[6] David M. Pozar, "Microwave engineering", John wiley & sons, INC., 1998.