Simulation Results of a Dual-Band and Shaped-Beam Array Feed for an Offset Parabolic Reflector

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Abstract

For a convenient portable earth station, an offset parabolic reflector with an array feed is considered. In this study, abilities of the radiation pattern synthesis by the array feed are investigated. Here, a simple dual band array feed is developed. Exact radiation characteristics are obtained with electromagnetic simulations. As a result, almost uniform aperture distribution is achieved by radiation pattern synthesis of a simple array feed. Moreover, array feed configuration of very low mutual coupling between dual frequency feeds is clarified. Finally, from the radiation patterns of the reflector antenna, high antenna gains and low spillover levels are ensured.

Keywords : Radiation Pattern synthesis Dual band array Moment methods offset parabola

1. Introduction

For a convenient portable earth station of satellite communication, offset parabolic reflectors are employed [1],[2]. In order to satisfy the light weight and cheap price, employment of a patch antenna as a feed is requested. In this case, antenna performance enhancement can be achieved by radiation pattern synthesis of the array feed. In this paper, abilities of the radiation pattern synthesis by the array feed are investigated. Through electromagnetic simulations many electrical characteristics are clarified.

2. Antenna Configuration

The antenna configuration is shown in figure 1. An offset parabolic reflector is fed by an array feed. The radiation pattern ($E_f(\phi)$) of the array feed is designed to achieve almost uniform aperture distribution ($E_d(\rho)$) on the reflector. The configuration of the array feed is shown in figure 2. In earth station antennas for satellite communications, dual band operations are requested corresponding to the up and down links. Here 14 GHz and 11 GHz are selected for the up and down links, respectively. In 11 GHz band, the 7 by 3 array configuration is employed. The 7 column elements are arranged with spacing of a half wavelength and have the excitation coefficients of [V] that is shown in figure 3. Three column arrays are arranged with spacing of a half wavelength. For the 14 GHz column array, the same design as the 11GHz array is adopted. The 14 GHz column arrays are arranged between the 11 GHz arrays. Moreover, in order to reduce mutual coupling between the 11 GHz and 14 GHz arrays, 14 GHz array are placed higher than the 11 GHz array.

3. Simulation Parameters

For calculations of antenna radiation characteristics, a commercial electromagnetic simulator FEKO is employed. And the scheme of MoM is utilized. Simulation parameters of a personal computer and simulation objects are summarized in table 1. Thickness of the dielectric substrates in 14 GHz is bigger than that of 11 GHz. Mesh sizes are automatically selected according to the sizes of the objects. The total mesh number becomes about twenty thousands. In calculating the antenna radiation pattern, it takes about 3 hours.

Table1:Simulation Parameters

Computer	Clock time: 3.2 GHz , Memory: 16Gbyte	
Simulator	FEKO (suit 6.0)	Method of moment
Array feed	ε_r	2.2
	tan δ	1.0×10^{-4}
	Thickness(11 GHz)	0.8 mm
	Thickness(14 GHz)	1.6 mm
	Mesh size	0.8～4.7 mm
	Number of mesh	11549
Reflector	Mesh size	4.85 mm
	Number of mesh	7411
Cal. time	3.0 hours	

4. Design of the Shaped Beam in the Array Feed [3]

The radiation pattern ([F]) of an array feed is expressed as [F] = [B][V]. Here, [V] expresses array excitation coefficients and [B] expresses contributions of [V] to the radiation pattern of [F]. When we design the objective radiation pattern ([A]), the radiation pattern difference (ε) of [F] - [A] is given by the next expression in the least mean square method (LMS).

$$\varepsilon = ([T][B][V]-[T][A])^{H} \times ([T][B][V]-[T][A]) \quad (1)$$

Here, H indicates complex conjugate and transpose of a matrix. [T] is a weighting matrix, which has only diagonal components (t_i). The minimum value of Eq. (1) is achieved when [V] is given by the next expression [4]. Here, $[T]^H[T]$ is converted to $[T_0]$.

$$[V_0] = ([B]^{H}[T_0][B])^{-1}[B]^{H}[T_0][A] \quad (2)$$

The designed results of the equation (2) are shown in figure 3. The achieved radiation pattern ($E_f(\phi)$) based on $[V_0]$ is shown in figure 4. The angular region $\phi_L<\phi<\phi_U$ faces to the reflector and the radiation pattern shape of this region is very important. Radiations outside the $\phi_L<\phi<\phi_U$ region are designed to be low levels because those radiations become spillover from the reflector. In order to achieve the objective radiation pattern, the element values of [T] are selected as shown in the figure. The aperture distribution ($E_d(\rho)$) is shown in figure 5. Almost uniform distribution is achieved except the reflector edge region.

5. Simulation Results

Detailed radiation characteristics are clarified through electromagnetic simulations. The 3-D radiation patterns of the array feeds are shown in figure 6. From the top and side views of radiation patterns, it is understood that radiation patterns in the column directions are well shaped. However, radiation patterns in the row directions are not shaped in this case. Aperture distributions are shown in figure 7. It is anticipated that almost constant distributions are achieved in the vertical planes. However, aperture high intensities are concentrated to the central parts in the horizontal plane. Moreover, in figure 7 (b) of 14 GHz case, slight asymmetry in the horizontal plane is observed. The reason of this asymmetry may be due to the mutual coupling affected by the 11 GHz array feed. So, current distributions are obtained in the case of the 14 GHz array excitation. The simulation results are shown in figure 8. Induced currents on the 11 GHz array elements are observed. Here, induced currents of 11 GHz array placed outside the column1 become rather weak. Therefore, affects for the asymmetry becomes very small. Finally, radiation patterns of the offset parabolic reflector are shown in figure 9. The θ=90 degree corresponds to the antenna front. Excluding the spillover area, very low sidelobe characteristics are achieved. In the backward direction of the reflector, spillover levels are decreased in 14 GHz.

6. Conclusion

Effects of array feed for an offset reflector are ensured through electromagnetic simulations. Important results are as follows. (1) Sufficient radiation pattern synthesis can be achieved by the 7 element array. (2) A dual frequency array feed with small mutual coupling can be achieved. (3) Antenna radiation patterns of high gain and small spillover characteristics are obtained.

References

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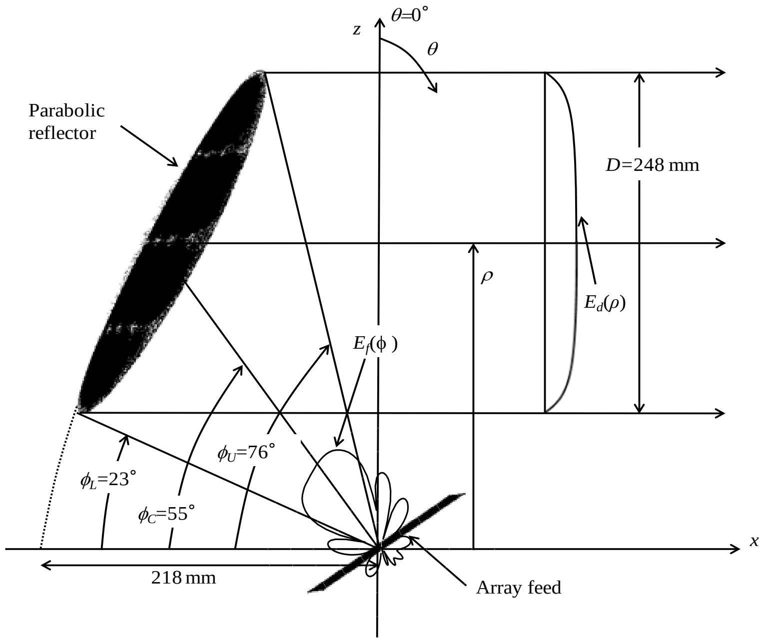


Figure 1: Antenna configuration.

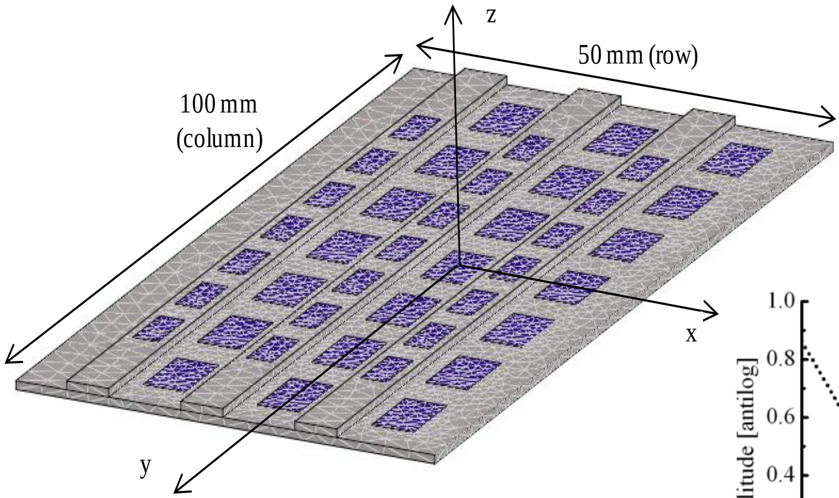


Figure 2: Array feed configuration.

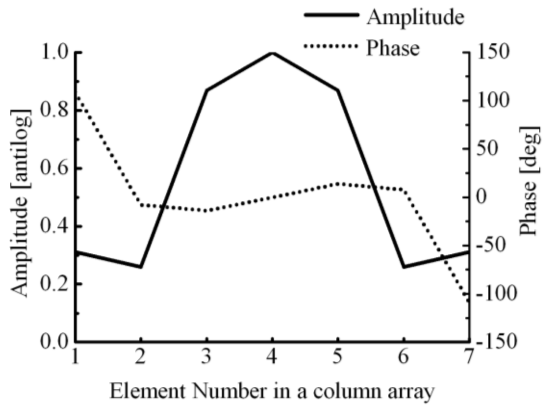


Figure 3: Excitation coefficients.

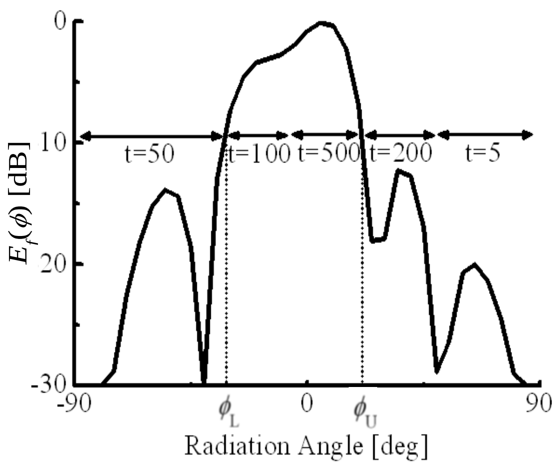


Figure 4: Synthesized array pattern.

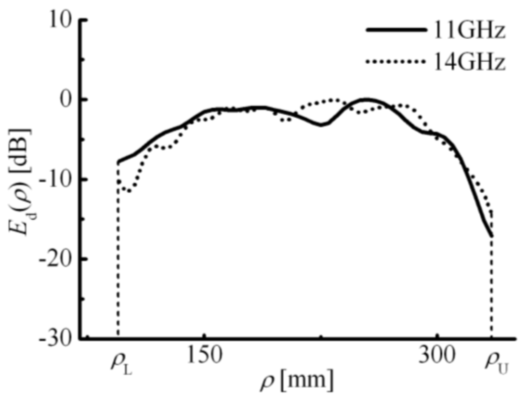
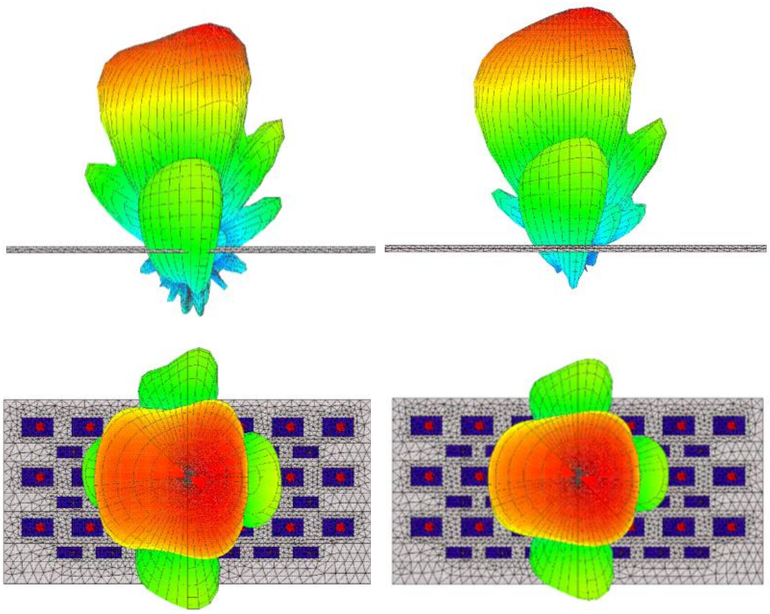
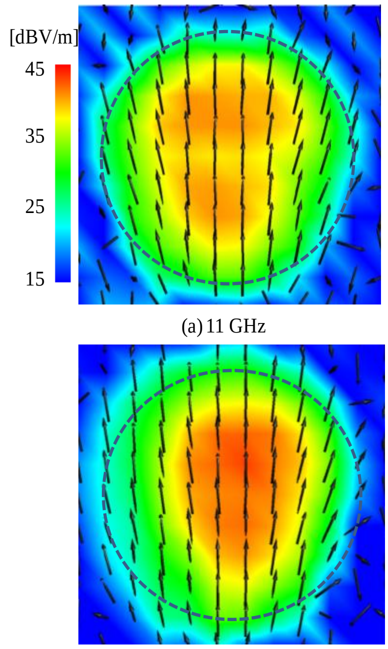


Figure 5: Aperture field distribution.



(a)11GHz (b) 1 4 GHz

Figure6: Radiation patterns of the array feeds.



(a) 11 GHz

(b) 14 GHz

Figure7: Aperture distributions.

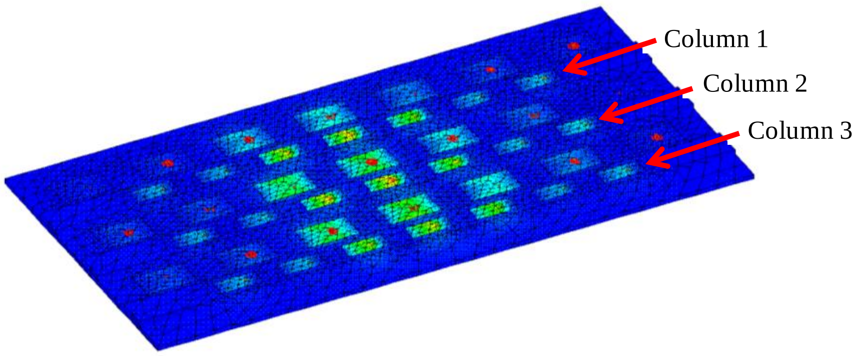


Figure8: Current distributions at 14 GHz.

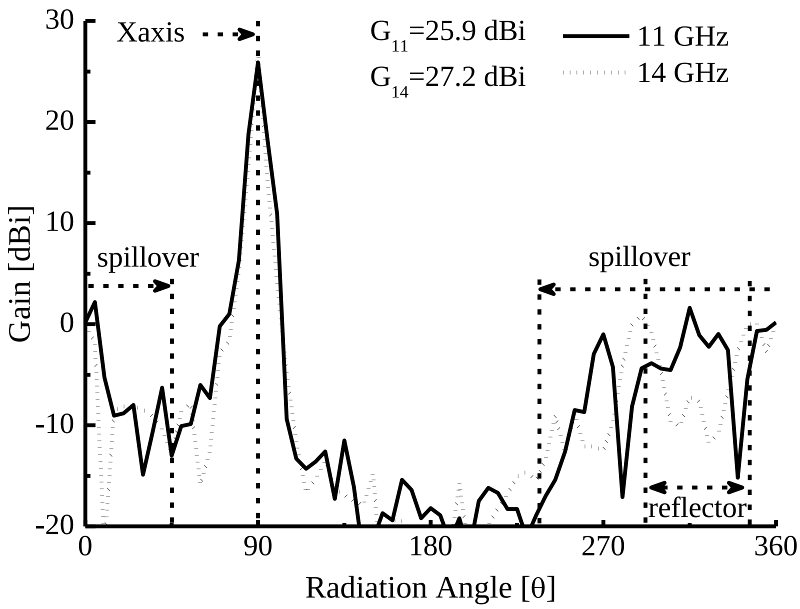


Figure9: Antenna radiation patterns in the vertical plane.