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Shaped-Beam Radiation Pattern of Imaging Reflector Antenna for Ka-band Broadcasting Satellites

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1. Introduction

Ka-band is expected for the next generation satellite of broadcasting, though rainfall seriously attenuates the signals [1]. In order to overcome this attenuation, a shaped-beam antenna with an intensified beam by an offset parabola antenna (OPA) has already been proposed. OPAs can provide an intensified beam to an arbitrary city adding to a uniform beam over the service area. However, the radiation power efficiency of OPAs is low due to the nonuniform excitation amplitude of the feed array [2]. To improve this problem, a method of restricting the peak excitation power has been reported [3].

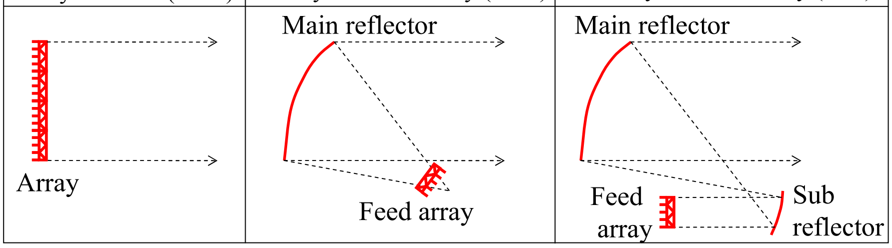
In this paper, an imaging reflector antenna (IRA) with the uniform excitation amplitude is proposed as a solution for the inefficiency problem. IRAs originally have full radiation power efficiency. IRAs are electrically equivalent to direct radiation array antennas (DRAs) magnified on the aperture plane of the main reflector. Therefore IRAs have the same performance as DRAs with large apertures, regardless of fewer feed elements.

We attempted to shape the radiation pattern over the following cases using a uniform excitation amplitude.

1. One uniform beam over Japan.
2. One uniform beam over Japan and one intensified beam to an arbitrary city.

Table 1 Shaped-beam antenna structures.

Direct Radiation Array Antenna (DRA)	Offset Parabola Antenna Fed by Antenna Array (OPA)	Imaging Reflector Antenna Fed by Antenna Array (IRA)



2. Antenna Configuration and Calculation Method

The IRA configuration and its parameters are shown in Fig. 1 and Table 2 respectively. The two parabolic reflectors share a common focal point, and the feed array is set at the conjugate point of the main reflector [4]. The each excitation amplitude of the feed array is made uniform, and only the each excitation phase is optimized to realize a required radiation pattern. The feed element directivity is approximated by a cosine function. The evaluated points are every 0.05° intervals in the

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service area shown in Fig. 2.

The current induced on the reflectors is calculated by PO (physical optics) method. The performance function F is defined by

$$F = \sum_{m=1}^{M} [G_m - D_m]^2 , \quad (1)$$

where M is the number of evaluated points, G_m is the calculated gain, and D_m is the desired gain at the evaluated point m. The steepest descent method is used to minimize the function F.

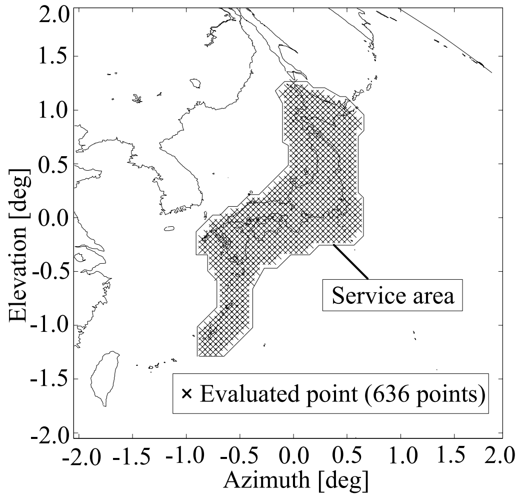
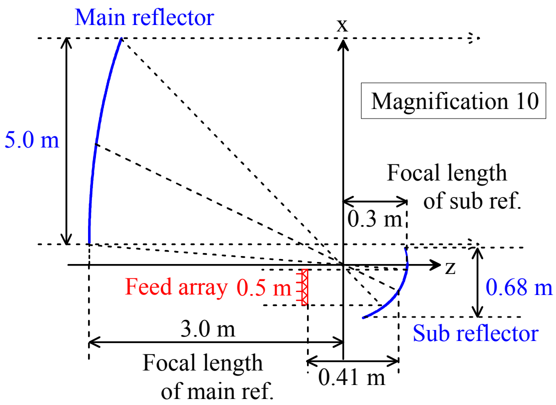
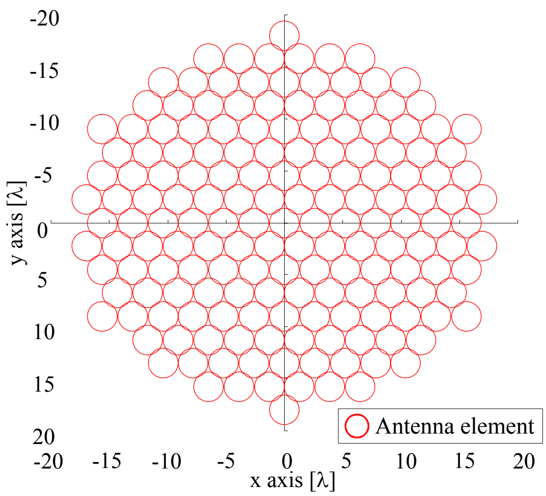


Fig. 2 Service area and evaluated points.



(a) Arrangement of feed array and reflectors.



(b) Arrangement of feed elements.

Fig. 1 Antenna configuration.

Table 2 Calculation parameters.

Orbit	Geostationary orbit (110° E)
Frequency	21.7 GHz
Magnification	10
Optimized parameter	Excitation phase
Main reflector	
Aperture diameter	5.0 m
Focal length	3.0 m
Sub reflector	
Aperture diameter	0.68 m
Focal length	0.3 m
Feed array element	
Interval	2.6 λ
Directivity	$\cos^{16.2}\theta$
Arrangement	Triangular arrangement

3. Results

One uniform beam over Japan is obtained as shown in Fig. 3 and Table 3. The points on land in the service area is covered by at least 40 dBi. As to the whole service area, the maximum gain is 42.8 dBi, the minimum gain is 38.3 dBi, and the average gain is 40.7 dBi. The low gain points are only along the outer edge of the service area.

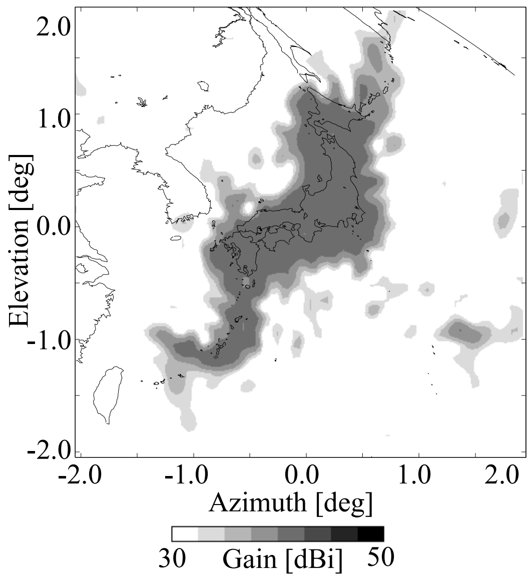


Fig. 3 Uniform beam pattern.

Table 3 Gain of uniform beam.

	Uniform beam
Maximum gain	42.8 dBi
Minimum gain	38.3 dBi
Average gain	40.7 dBi

Then, one intensified beam to an arbitrary city in addition to one uniform beam over Japan is obtained. Fig. 4 and Table 4 show the results when the intensified beam is toward to Tokyo, Fukuoka or Sapporo, for examples. The intensified beam is more 10dB higher than the average gain of the uniform beam. However, the minimum gain is reduced by about 3 dB and the average gain is reduced by 0.4 dB. An undesired high-gain point with a gain of more 40 dBi appeared in Fig. 4(c) is due to the grating lobe effect.

4. Conclusion

The proposed IRA with the uniform excitation amplitude has full radiation power efficiency. It can shape one uniform beam over Japan with one intensified beam that saves serious rainfall attenuation at an arbitrary city.

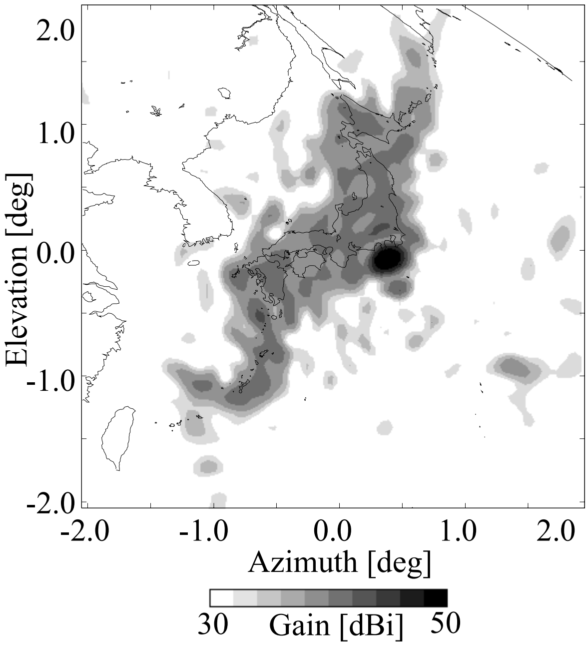
References

[1] S. Tanaka, H. Minematsu, T. Saito, H. Matsumura, “Basic study on the advanced broadcasting satellite system,” Technical Report of IEICE, AP2000-56, pp.85-91, July 2000.

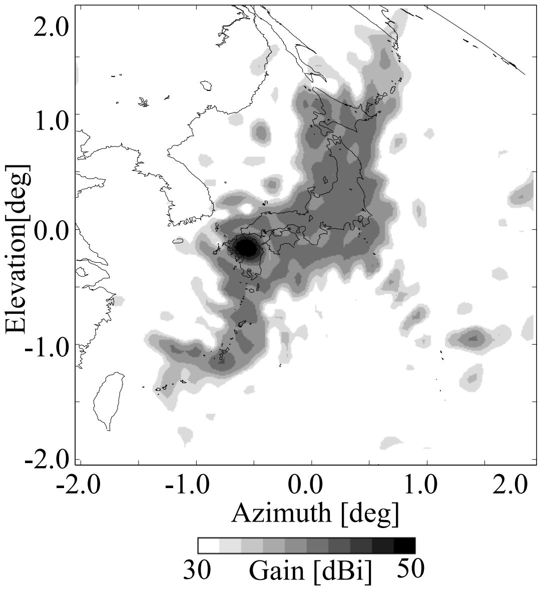
[2] S. Tanaka, T. Murata, “Effect of Restricted Excitation Power of Elements for Array-fed Single Reflector Antenna,” Technical Report of IEICE, AP2002-119, pp.1-6, Jan. 2003.

[3] S. Tanaka, T. Yamada, T. Murata, “A Study on Radiation Pattern of On-Board Array-Fed Reflector Antenna for Direct Broadcasting Satellite,” Technical Report of IEICE, AP2001-169, pp.61-67, Jan. 2002.

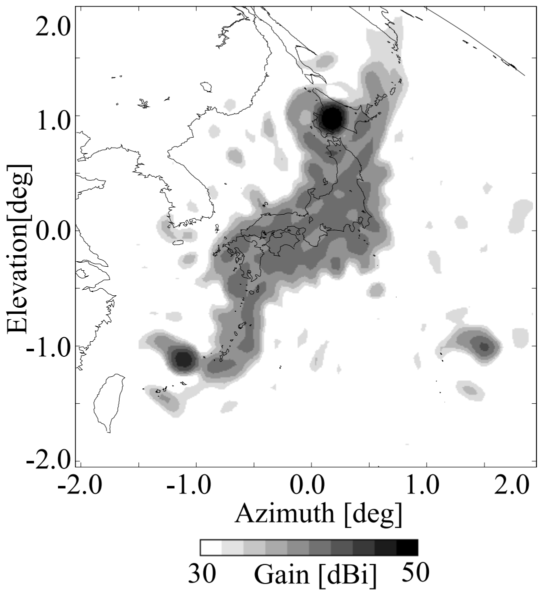
[4] C. Dragone and M. J. Gans, “Imaging Reflector Arrangements to Form a Scanning Beam Using a Small Array,” The Bell System Technical Journal, Vol.58, No.2, pp.501-515, Feb. 1979.



(a) Tokyo intensified.



(b) Fukuoka intensified.



(c) Sapporo intensified.

Fig.4 Intensified beam pattern.

Table 4 Intensified beam gain.

	10 dB intensified beam		
	Tokyo	Fukuoka	Sapporo
Maximum gain	51.3 dBi	51.1 dBi	51.3 dBi
Minimum gain	36.1 dBi	35.4 dBi	35.6 dBi
Average gain	40.3 dBi	40.4 dBi	40.3 dBi