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AN APPLICATION OF ARRAY-FEEDS TO MULTIBEAM RECEIVING EARTHSTATION ANTENNAS FOR DOMESTIC COMMUNICATIONS SATELLITES OF JAPAN

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1. Introduction

We are now facing at "Multi-satellites Age", and demands for multibeam antenna are increasing more than ever.

For the design of multibeam antenna, it is important to suppress phase error, which causes antenna gain degradation. Most of multibeam antennas have respective solutions for this problem.

It is one representative method to control path length geometrically such as shaping the main reflector or employing shaped subreflectors.

On the other hand, there is another approach to this problem, that is, to compensate the phase error with an array-feed whose elements are excited with adequate amplitude and phase. There are some reports about this concept, especially from a standpoint of beam steering or compensation of antenna reflector surface distortion.

The application of this concept to a multibeam receiving antenna for domestic communications satellites in Japan is discussed in this report.

2. Approach [1]-[2]

The determination of each excitation coefficient is based on the concept of *"focal-plane match"*. Basically, this method is based on the knowledge of the field distribution on the focal-plane.

But here, we utilized the following approach simplified according to the reciprocity theorem.

1) At first, fix the location of the array-feed elements.

2) Calculate the far field made by one element to the desired direction (to the satellite).

3) Let the conjugate of the far field obtained in 2) be the excitation coefficient of this element.

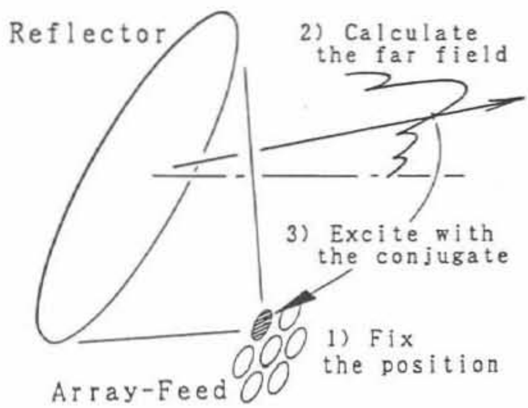


Fig.1 Determination of excitation coefficients

4) Repeat the above calculation for each element.

The determination of the excitation coefficients described above will maximize the antenna gain.

3.Numerical Simulation

In the near future, four domestic communications satellites will be on the stationary orbit between 150 E and 162 E with 4 deg. interval. In this report, we will examine simultaneous receiving from these four satellites with the off-set paraboloid reflector shown in Fig.2.

These satellites will be observed from the mainland of Japan on an arc with 4.5 deg. interval. It means that the antenna must have four beams to the direction ±2.25 deg. and ±6.75 deg. off-axis as shown in Fig.2.

These satellites make power distribution on the focal plane (Fig.2). As shown in this figure, the distribution made by Sat.1 (6.75 deg.) is far more distorted than that by Sat.2 (2.25 deg.). Therefore, we would like to restrict the discussion to the 6.75 deg. beam.

Here, the following cases are examined.

a) 1 horn

b) 19 elements

c) 16 elements

d) 11 elements

e) 16 elements with digitized excitation coefficients

The elements of the 4 cases from "*b*" to "*e*" are assumed to be circular patch antennas.

The characteristics have been calculated at 12.5 GHz. The results are shown in Fig.3 to 7 (the position of each elements in (A), the composite primary pattern in (B) and secondary pattern in (C)). And each efficiency is compared in Table 1.

4.Discussion

Since we are now considering the application to the receiving-only antenna, we will discuss mainly paying attention to the efficiency.

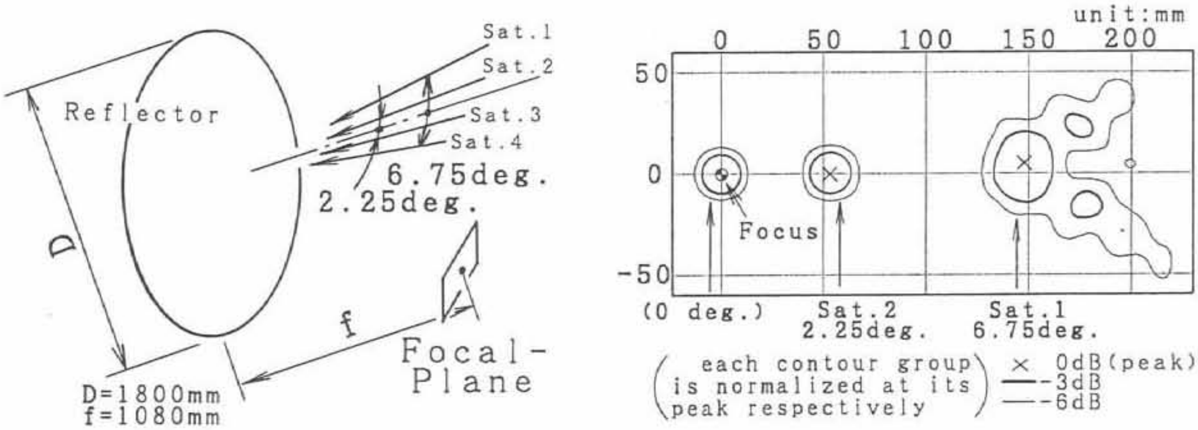


Fig.2 Off-set paraboloid antenna and field distribution on the focal-plane

4.1 Effect of the array feed

In the case "*b*", we can see considerable improvement, especially in phase efficiency, by employing the 19 element array-feed.

4.2 Reduction of element number

The elimination of the elements is examined here.

In the case "*c*", three elements are eliminated form the case "*b*". The effect of this elimination is only 0.2 dB gain degradation as shown in Table 1.

In the case "*d*", four more elements are eliminated from the case "*c*". The efficiency is degraded significantly due to spillover loss (see Fig.6 and Table 1). More elements are required to suppress the spillover loss.

4.3 Effect of digitization

In the actual implementation, it may be desirable to digitize the excitation amplitude. In addition, the excitation coefficients may be changed because of unexpected factors such as mutual coupling or manufacturing error, etc.

Here, the effect of the digitization are examined (3 dB step in amplitude and 30deg. step in phase).

As shown in Fig.,7 and the case "*e*" in Table 1, the effect of the digitization is comparably small. The determination of the excitation coefficients has some allowances.

5.Conclusions

In this report, we have examined the application of the array-feed to a multibeam receiving earthstation antenna with a paraboloid reflector. As a result, the following has become clear.

1) The array-feed is applicable to multibeam receiving antennas.

2) Some elimination of the elements is possible.

3) The determination of the excitation coefficients has some allowances.

It is necessary to verify its performance through experimental evaluation.

References

[1] Y. Rahmat-Samii : "Array Feeds for Reflector Distortion Compensation : Concepts and Implementation", IEEE Antennas and Propagation Magazine, pp.20-26 (August 1990)

[2] S. J. Blank and W. A. Imbriale: "Array Feed Synthesis for Correction of Reflector Distortion and Vernier Beamsteering", IEEE Trans. **AP-36**,10, pp.1351-1358 (October 1988)

Table 1 Efficiencies[dB] (12.5GHz)

Case	*a*	*b*	*c*	*d*	*e*
Element	Horn	19	16	11	16*
Illumination	-1.26	-0.97	-1.06	-1.11	-1.06
Spillover	-0.32	-0.67	-0.76	-1.48	-0.92
Cross pol.	-0.05	-0.06	-0.06	-0.06	-0.06
Phase error	-5.24	-0.73	-0.75	-1.02	-0.76
Total	-6.87	-2.43	-2.63	-3.67	-2.80

* Digitized coefficients

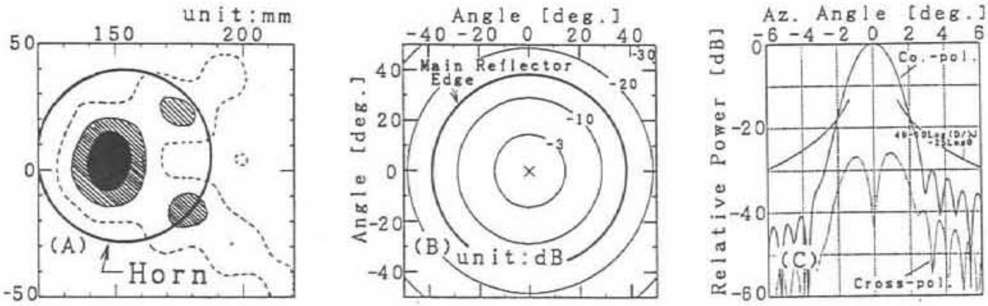


Fig.3 Characteristics in the case "*a*" (1 Horn)

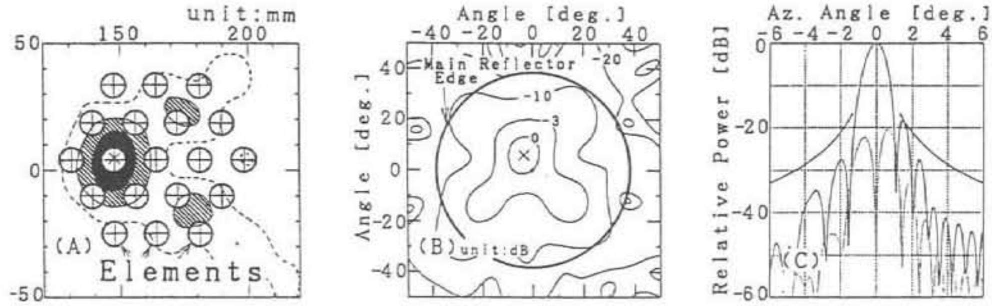


Fig.4 Characteristics in the case "*b*" (19 Elements)

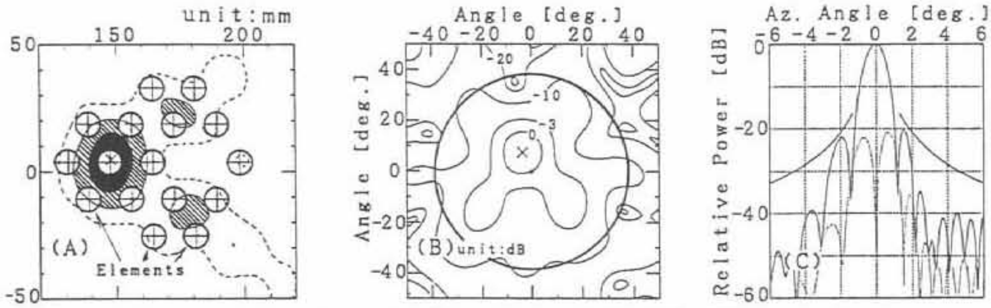


Fig.5 Characteristics in the case "*c*" (16 Elements)

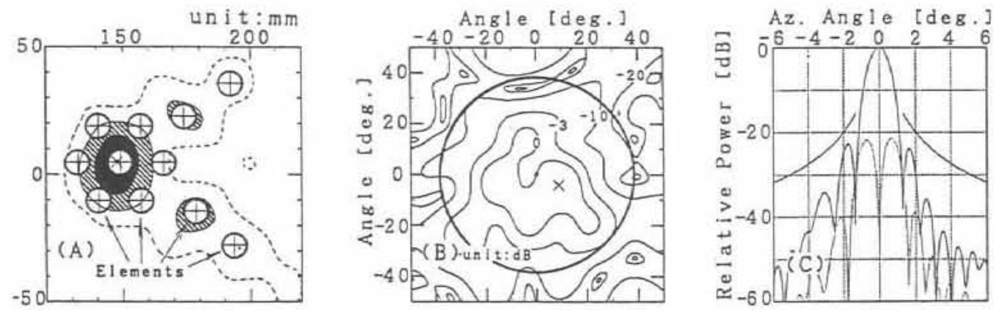
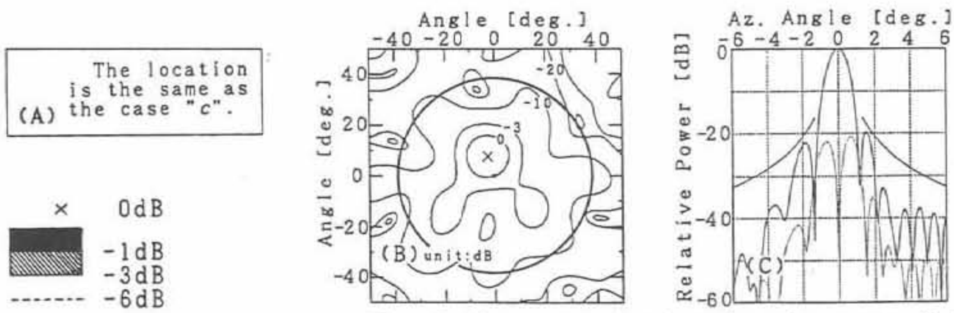


Fig.6 Characteristics in the case "*d*" (11 Elements)



(A) Element Location
(B) Primary Pattern
(C) Secondary Pattern

Fig.7 Characteristics in the case "*e*"
16 Elements with digitized
Excitation Coefficients
Amp.:3dB Step, Phase:30deg. Step