A PATTERN SYNTHESIS METHOD FOR A MULTIPLE BEAM REFLECTOR ANTENNA WITH CLUSTER FEEDS

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Introduction

Multiple beam antennas are attractive for satellite communications because of their large communication traffic load handling capacity. There are several requirements, such as efficient regional coverage and low cross-polarization. Also, it is necessary for frequency reuse applications to achieve high isolation between adjacent main beams operated over the same frequency band. This isolation problem is very important. To achieve good isolation, reflector antennas with cluster feeds were considered(1); however, it is difficult to determine the applicable weights for cluster feeds.

To overcome this difficulty, the authors introduce a pattern synthesis method using the adaptive algorithm(2), which determines the cluster feed weights. The adaptive method is to obtain patterns which have nulls in the directions of interferences and which preserve the gain in the desired directions. By setting the interference directions to the sidelobe desired to make low level, patterns can be obtained satisfying the isolation requirement, and the optimum weights for cluster feeds are determined explicitly. Furthermore, this synthesis method has advantages in that optimization is accomplished without iterations and only a short time is needed to calculate.

A Cassegrain antenna with a cluster feed is considered here. An attempt is made to obtain low sidelobe patterns and to determine optimum weights of cluster feeds with this synthesis method. Some numerical results are shown in order to indicate the effect of this synthesis method.

Synthesis Method

Figure 1 shows an offset Cassegrain antenna system with cluster feeds. A cluster feed to generate one beam consists of 7 horns and lies on the focal plane of the subreflector as shown in Fig. 1(b).

The far field pattern for a Cassegrain antenna with a single feed horn is illustrated in Fig. 2. The radiation field is calculated by Geometrical Theory of Diffraction (GTD) for the subreflector and by Physical Optics (PO) for the main reflector. Because the GTD includes the diffraction at the subreflector edge, the field is obtained accurately.

As shown in Fig. 2, sidelobes generated by single horn feed are insufficient for the isolation. Therefore cluster feeds are used and cluster feed weights are determined to reduce the sidelobe level using an adaptive synthesis method. To preserve the gain on a main beam area, it is necessary to constrain the main beam direction in the form of

$$C^T W = H \tag{1}$$

where W is a weight vector, H is a response vector, C is a constraint matrix, and superscript T denotes transpose.

Under this constraint condition, minimizing the output power which is generated by inputs of specific directions, total fields in the specifid directions are sent to null except in the constraint directions. Optimum weights are given

$$W_{opt} = \mathbb{R}_{xx}^{-1}\,\mathbb{C}\,[C^T R_{xx}^{-1} C]^{-1} H \qquad (2)$$

where $\mathbb{R}_{xx}$ is called a covariance matrix, and expresses the output correlation for each horn. The cluster feed, weighted by Eq. (2), generates a far field pattern which has good isolation.

Numerical Result

Let us assume that beam 1 and 3 in Fig. 2 operate over the same frequency band. The parameters of the offset Cassegrain antenna are indicated in Table 1. The pattern obtained by the adaptive synthesis method is shown in Fig. 3. The single horn feed pattern is shown simultaneously for comparison. Here, cluster feed weights are obtained which make sidelobes lower in 4 directions indicated by arrow heads. Weights are indicated in Table 2. From Fig. 3, it is found that the adaptive synthesis method can improve a sidelobe by more than 8 dB. As a result, in beam 3 region, the interbeam isolation is less than 35 dB, which satisfies a communication satellite isolation level (less than 27 dB) and a TV broadcasting satellite isolation level (less than 35 dB). In Fig. 4, the pattern synthesized for beam 3 is shown. Weights are indicated in Table 3. Even though the beam 3 is off axial, a good isolation pattern can be obtained.

Conclusion

This paper has presented a pattern synthesis method which uses the adaptive array technique. As a result of numerical calculations, a good isolation pattern has been obtained for an offset Cassegrain antenna with a cluster feed, and the optimum weights for the cluster feed have been determined explicitly. This method has the advantage that an interfering sidelobe level can be reduced directly without main beam gain degradation. Therefore, this synthesis method is useful for a multiple beam antenna design.

References

(1) V. Galindo-Israel, S. W. Lee and R. Mittra, "Synthesis of a laterally displaced cluster feed for a reflector antenna with application to multiple beams and contoured patterns", IEEE Trans., AP-26, No. 2, March 1978.

(2) K. Takao, M. Fujita and T. Nishi, "An adaptive antenna array under directional constraint", IEEE Trans., AP-24, No. 5, September 1976.

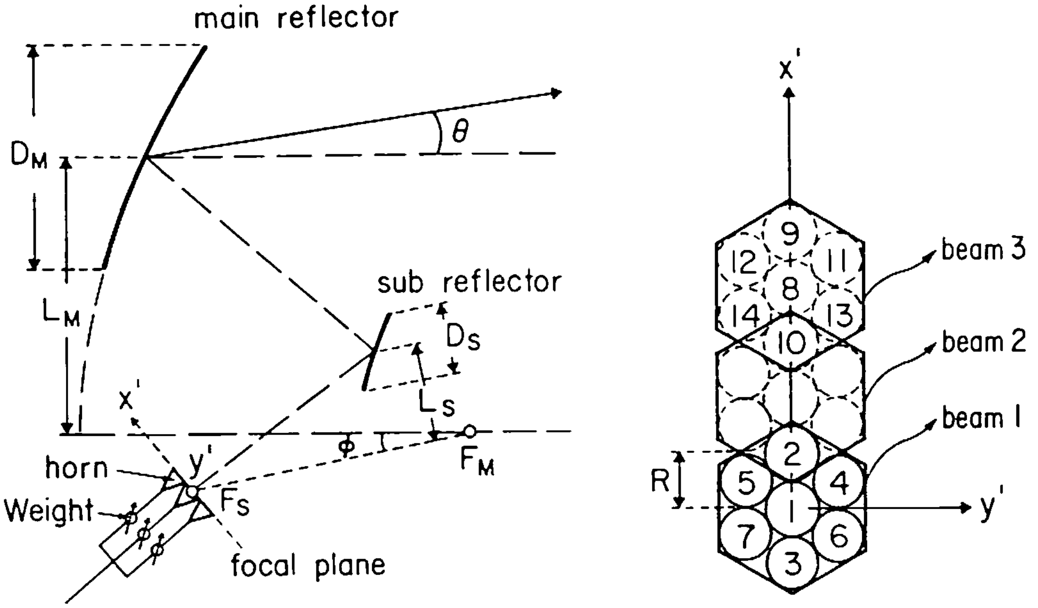


Fig.1 (a) Geometry of the Cassegrain antenna

(b) Configuration of cluster feeds

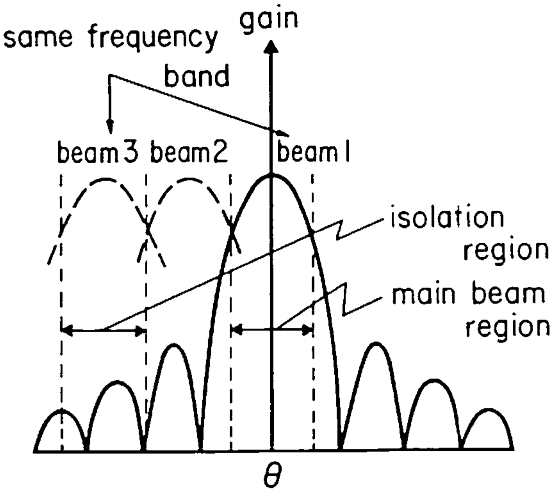
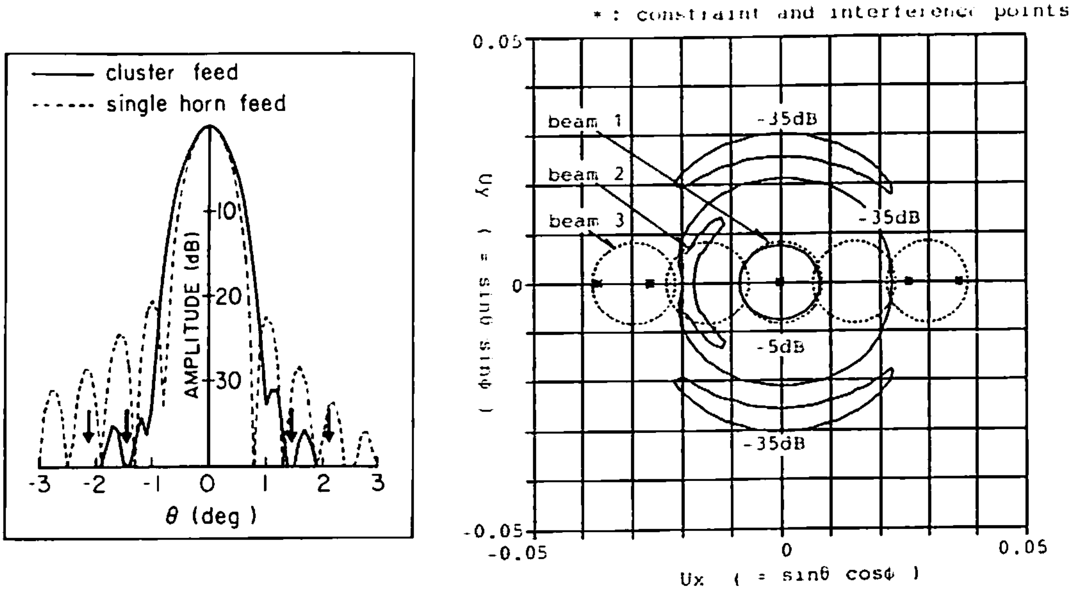


Fig.2 Far field patterns

Main reflector
D_M = 101.22 λ L_M = 105.09 λ focal length = 86.0 λ
Sub reflector
D_S = 40.0 λ L_S = 25.0 λ focal length = 35.0 λ eccentricity = 1.836
R = 3.0 λ

Table 1. Parameters



(a) (b)

Fig. 3 Patterns of beam 1

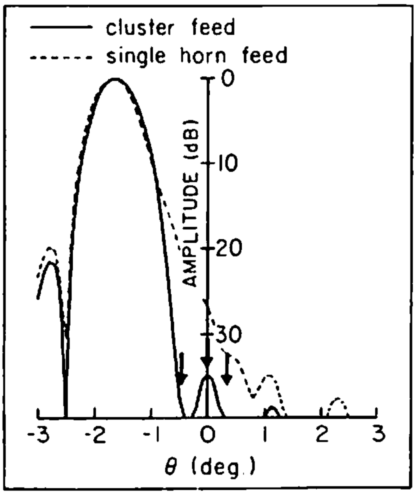


Fig. 4 Patterns of beam 3

Table 2
Weights of the cluster generating beam 1

Horn	Amplitude	Phase(deg.)
1	1.000	0.0
2	1.076	-107.5
3	1.000	-223.7
4	0.459	-64.5
5	0.459	-64.5
6	0.442	-298.4
7	0.442	-298.4

Table 3
Weights of the cluster generating beam 3

Horn	Amplitude	Phase(deg)
8	1.000	0.0
9	0.133	-211.4
10	0.576	-332.1
11	0.489	-35.3
12	0.489	-35.3
13	0.204	-344.1
14	0.204	-344.1