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A MULTIPLE SHAPED–BEAM ANTENNA USING A SINGLE SHAPED REFLECTOR

Hiroki SHOKI and Kazuaki KAWABATA
Toshiba Research and Development Center
1, Komukai Toshiba–cho, Saiwai–ku, Kawasaki, 210 JAPAN

1. INTRODUCTION

Multibeam antennas are very attractive for satellite communications and broadcasting because of their large communication traffic load handling capacity and their suitability for regional broadcasting. The most important problem in designing multibeam antennas is how to use limited frequency resources effectively. For reflector antennas, the most popular way to solve this problem is to synthesize low sidelobe radiation patterns by using cluster feeds and optimizing their excitation weights. But this method has some disadvantages: the cluster feeds are large, their beam–forming networks are complex, and they result in insertion power loss.

Recently, much interest has been shown in the single–feed shaped reflector antenna. This type of antenna, though using a simple feed configuration, generates a shaped beam which matches the desired coverage region and/or has low sidelobe levels in the region where good isolation is required. Applying this shaped reflector concept, the authors propose here a multiple shaped–beam antenna. This is a multibeam antenna where all beam patterns are shaped and their sidelobes are reduced by reflector shaping. This new concept is very attractive for use as a satellite antenna because it requires only a single reflector and simple feeds. In this paper, the authors describe the design procedure and give a design example.

2. REFLECTOR SHAPING METHOD

Several methods for the design of shaped reflectors have been published in the literature[1]–[3]. The authors have also proposed a reflector shaping method[4] which is based on the assumption of an array equivalent to a reflector antenna. This method has much flexibility; for example, it can be applied to beam shaping which is effective over more than two frequency bands. The authors explain here another application to multiple beam shaping.

Figure 1 shows a single shaped reflector antenna which generates multiple shaped beams. By dividing a single reflector into small elements, a shaped reflector antenna can be considered the equivalent of the array antenna as shown in Fig.2. By optimizing the phase distribution of this array, beam patterns of desired shapes can be obtained.

In this design procedure, the evaluation function Φ is defined as

$$\Phi = \sum_{i} \Phi i \qquad (1),$$

where Φi denotes the function of the i–th beam. Φi is written as,

$$\Phi i = \sum_k [P(s_k)-h(s_k)]^2 \qquad (2).$$

$P(s_k)$ is the radiated power in the direction s_k, and $h(s_k)$ is the desired value of radiative power. $P(s_k)$ is given by summing of each small element contribution which is calculated by Physical Optics (PO). Φ is a function of the element antenna phase θj, and the optimum phase distribution, which minimizes the evaluation function Φ, can be found by applying the method of steepest descent.

Once the optimized phase distribution is known, a reflector surface can be completely determined. By translating each element phase into ray path length and adjusting (moving) each small element, the shaped reflector surface is obtained.

In this procedure, the authors apply the following conditions:

(1) When the range of phase values is −180 degrees to 180 degrees, phase jumps occur at the points where the phase value changes from −180 degrees to 180 degrees. These jumps cause the discontinuity in the shaped reflector surface. To keep the shaped surface smooth, a constraint condition is applied in this optimization. The condition is that the maximum phase difference between adjacent elements is limited to an adequate value.

(2) When adjusting the small elements, the orientation of the small element plane is also adjusted considering the overall surface smoothness. After this adjustment, element radiation patterns may change from the initial situation, so element radiation patterns are calculated and input again into the optimization procedure till convergence.

3.DESIGN EXAMPLE

As an example, this method is used to design a reflector antenna which covers the main Japanese islands with four beams, with each beam shaped to realize twofold frequency reuse. In this case, the required isolation level is more than 20 dB. The diameter of the initial reflector is 200λ (λ is the wavelength in free space), and the F/D ratio is 0.6. The primary feed horns are $\phi 1.4\lambda$ and circularly polarizing, and their radiation patterns are assumed to be ideal $\cos^{3.5}\theta$.

Figure 3 shows the resulting shaped reflector configuration, where the difference from the initial parabolic surface is indicated. The maximum difference was 0.29λ. In this design, the reflector is divided into 1,600 small elements. Figure 4 shows calculated patterns for the designed reflector. Beam shaping was performed from two standpoints: to widen the beams, and to reduce the sidelobe level in the other region operating at the same frequency. In Fig.4, × indicates the direction where the gain was defined in this design. Each main beamwidth was increased as compared with a conventional parabolic reflector antenna and the sidelobe level was reduced to achieve more than 20 dB isolation.

4. SUMMARY

A multiple shaped beam antenna has been proposed and its design procedure was described. This antenna has great advantages to satellite communications and broadcasting because multiple shaped beams are realized with a very simple configuration. Numerical results indicate that more than 20 dB of isolation can be attained. This level is somewhat lower than for general multibeam antennas which use cluster feeds. However, this proposed antenna is very attractive for some applications in digital broadcasting and digital communications which require only 20 dB isolation[5].

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Fig.3 Designed shaped reflector

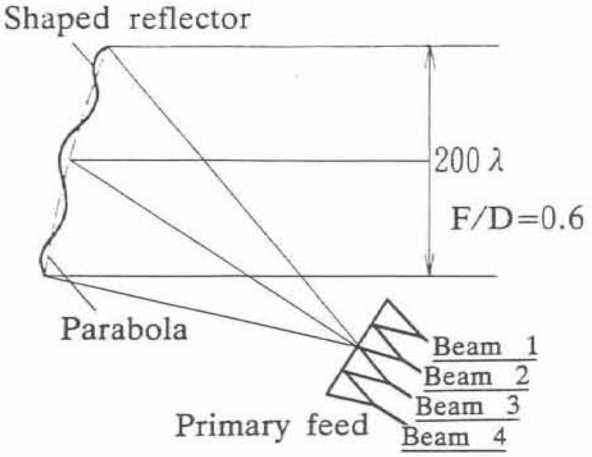

Fig.1 Shaped reflector antenna

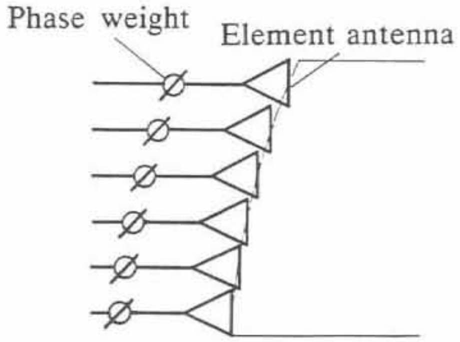

Fig.2 Equivalent array

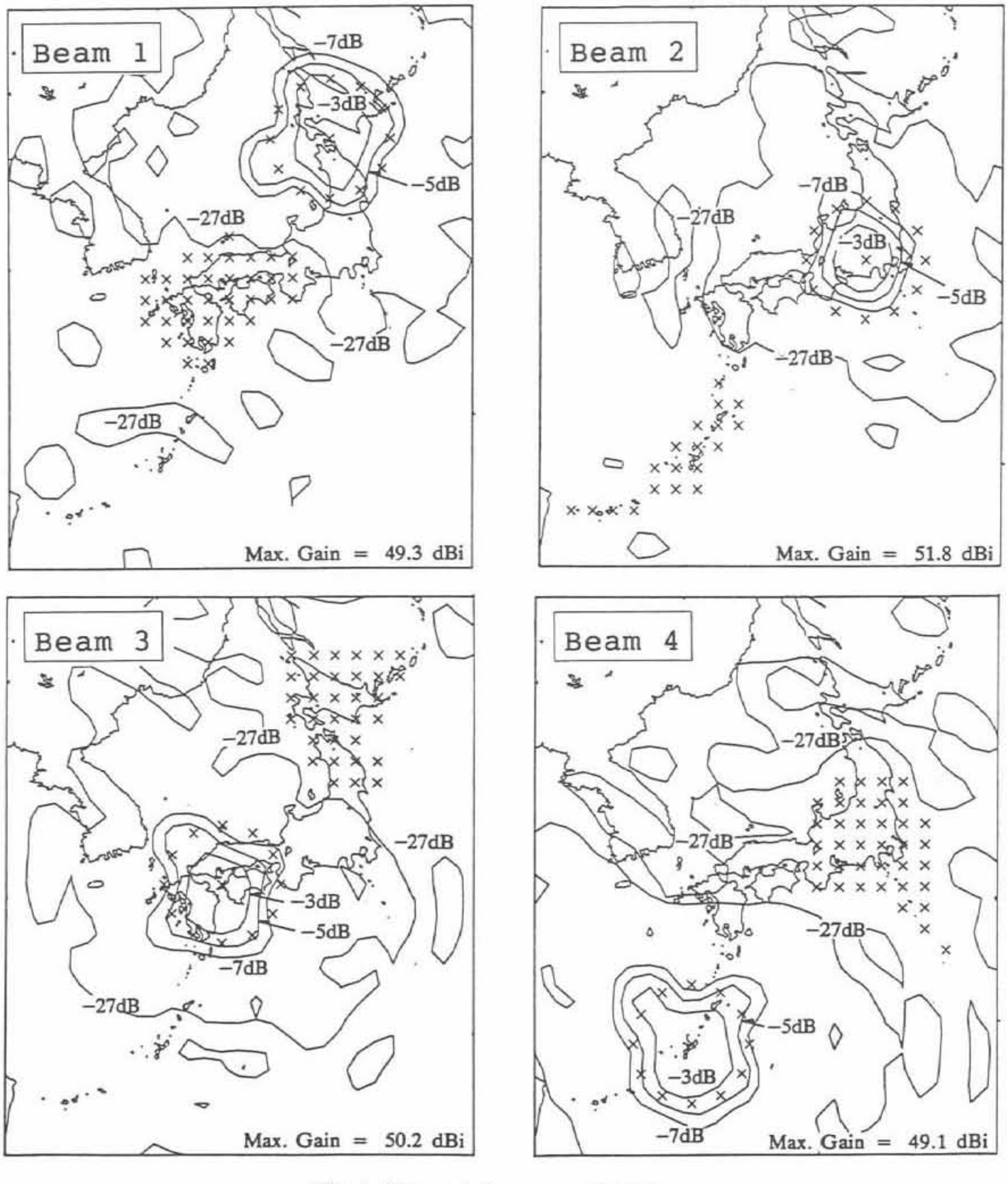

Fig.4 Shaped beam patterns