SHAPED REFLECTOR 6-SECTOR ANTENNA FOR BASE STATION APPLICATION IN FIXED WIRELESS ACCESS SYSTEMS

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1 Introduction

Point-to-multipoint (P-MP) fixed wireless access (FWA) systems are possible candidates to solve the so-called last-one-mile-problem of "Fiber To The Home" (FTTH), that is, the problem of cost and time to install last-one-hop optical fiber cables to subscribers[1, 2]. The P-MP FWA systems are also attractive as complementary systems of existing optical fiber networks, or to newly entering carriers, for cost-effective and installation-time-saving subscriber networks of their own.

For base station antennas in such systems, offset single reflector antennas were developed to radiate a beam with sector shape in the horizontal plane and cosecant-square shape in the vertical plane[3, 4]. In these antenna design, skillful reflector shaping technique was applied to achieve excellent beam shaping. However, these reflectors were required to be as large as several tens of wavelength in size. Furthermore, since these antennas radiated single beams, multiple antenna reflectors were required in order to cover multiple sector areas.

In this paper, we propose a novel shaped reflector 6-sector antenna. The antenna reflector is a torus reflector illuminated by 6-feed horns. The arrangement of the reflector and the feed horns is similar to an omni-directional horn-reflector antenna[5], but the proposed antenna reflector is illuminated by the 6-feed horns unlike an omni-directional horn-reflector antenna. The reflector surface is shaped to achieve a cosecant square-like radiation pattern in the vertical plane. The antenna is advantageous to radiate vertically shaped 6-sector beams simultaneously with a compact configuration.

2 Antenna Design

2.1 Antenna configuration

The antenna configuration is illustrated in Figure 1. The antenna is composed of a reflector and 6-feed horns. The reflector is a torus reflector whose axis of rotation is x-axis. The rotation radius is designed to achieve required beamwidth of 60 deg. in the horizontal plane. The generating line of the torus reflector is shaped from a parabola to achieve a cosecant square-like radiation pattern in the vertical plane, as described in the following section. Being different from an omni-directional horn-reflector antenna[5], the 6-feed horns are symmetrically installed on the locus circle of the initial parabola focus. In the current design, the feed horns are conventional square aperture horns excited by the fundamental mode for simple feed structure.

2.2 Reflector shaping

The shaped torus reflector results from the generating line shaped from a parabola. The generating line shaping is based on the path length difference (aberration) in the xz-plane including both a feed and the reflector symmetrical axis (x-axis). Figure 2 shows the schematic cross sectional illustration of generating line shaping in the xz-plane. In this figure, F is a feed point, M is an arbitrary point on the generating line, and $\boldsymbol{e}_s$ is a unit vector from F to M. The generating line is assumed to be shaped along $\boldsymbol{e}_s$ by amount s from an initial parabola. Path length increase δ due to shaping is given for rays on the xz-plane by:

$$\delta = s(1-\gamma), \quad \gamma = \boldsymbol{e}_s \cdot \boldsymbol{k}_B \tag{1}$$

where $\boldsymbol{k}_B$ is a unit vector representing the initial parabola axis.

On the other hand, we assume that the desired aberration δ is represented by a power series of an appropriate coordinate t of the point on the generating line[6] as:

$$\delta = \sum_m a_m t^m \tag{2}$$

$$t = \boldsymbol{\rho} \cdot \boldsymbol{i}_t = (\boldsymbol{\rho}_0 + s\boldsymbol{e}_s) \cdot \boldsymbol{i}_t = t_0 + \alpha s \tag{3}$$

$$t_0 = \boldsymbol{\rho}_0 \cdot \boldsymbol{i}_t, \quad \alpha = \boldsymbol{e}_s \cdot \boldsymbol{i}_t$$

where $\boldsymbol{\rho}_0$ and $\boldsymbol{\rho}$ are the position vectors of M on the initial parabola and a shaped generating line from the origin M_0, respectively, and $\boldsymbol{i}_t$ is the unit vector of the appropriate coordinate frame for t. We can calculate the shaping amount s by substituting (3) into (2) and equating with (1).

Provided that the power series coefficients a_m are determined, we can calculate the radiation pattern from the shaped reflector using the shaping amount s. Therefore, we can design the shaped reflector to achieve a desired radiation pattern shape by minimizing the square sum of the difference between desired and calculated patterns with respect to optimization variables a_m. In the current design, we apply the conjugate gradient method to minimization, and approximate the calculated radiation pattern by a summation of contributions from divided small segments of the reflector for calculation convenience.

2.3 Design result

Figure 1 shows a designed antenna. For the initial parabola, the focal length is 25mm, the inclined angle is 90 deg., and the subtended semi-angle is 45 deg. The radius of the locus circle of the initial parabola focus is 40mm. For the reflector shaping, the origin M_0 is at the top of the initial parabola, the coordinate frame for t is $-x$ direction, and orders of the power series considered in (2) are m =1 to 5[6]. Radiation patterns designed at 26GHz are shown in Figure 3. The patterns include only a contribution from current on the reflector, which is considered in reflector shaping. The radiation pattern in the vertical plane is well shaped to cosecant square-like shape, but the pattern in the horizontal plane has about 60 deg. beamwidth regardless of the reflector shaping.

3 Experimental Results

Figure 4 shows a photograph of the prototype antenna, and Figure 5 shows measured radiation patterns. For comparison, Figure 5 includes actual calculated patterns including both contributions of the reflector current and the feed horn. The patterns also include 3dB loss of a switch connected to the feed horn. In the vertical plane, although partial level reduction and some ripples appear in the measured pattern caused by the unexpected blocking and scattering by the structural parts, the measured pattern agrees well with the calculated pattern. In the horizontal plane, the agreement between the measured and the calculated is better. These experimental results validate the antenna design.

4 Conclusion

A novel shaped reflector 6-sector antenna has been proposed for a base station antenna in P-MP FWA systems. The antenna is composed of a torus reflector and 6-feed horns. The reflector surface is shaped to achieve a cosecant square-like radiation pattern in the vertical plane. The antenna is advantageous to radiate vertically shaped 6-sector beams simultaneously with a compact configuration. The prototype of the antenna was fabricated, and the antenna design was verified by experiment.

Acknowledgement

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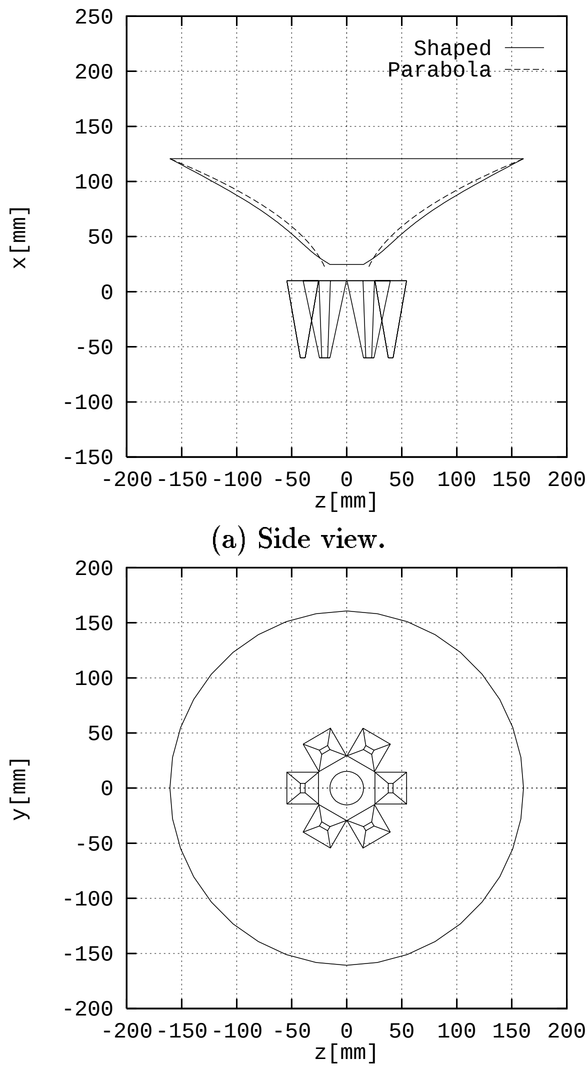


(a) Side view.

(b) Bottom view.

Figure 1: Antenna configuration.

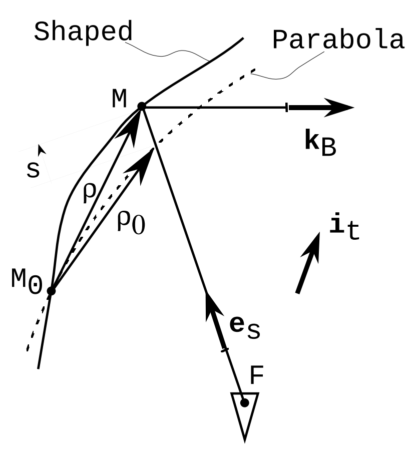
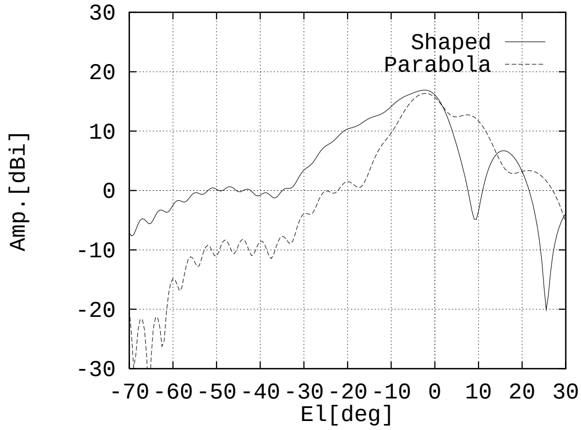
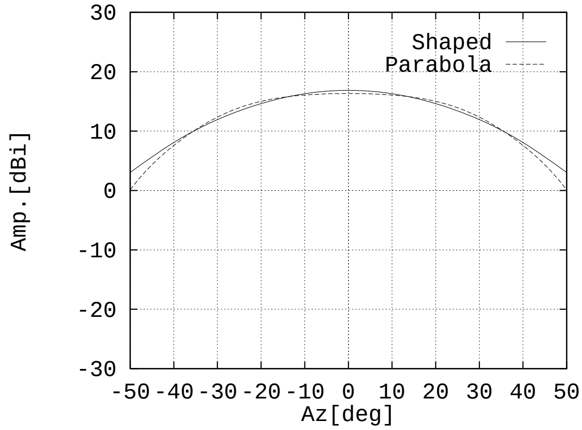


Figure 2: Schematic illustration of generating line shaping.



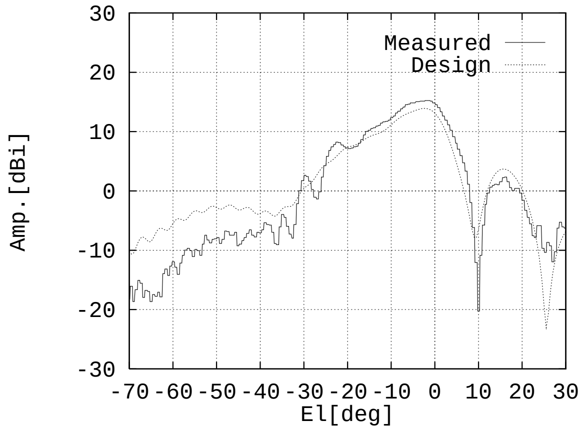
(a) Vertical plane (Az=0 deg.).



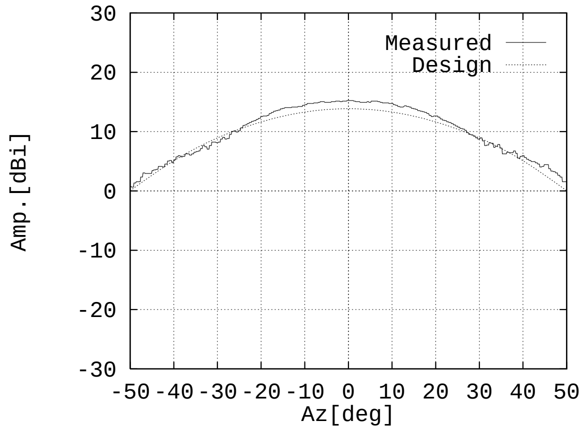
(b) Horizontal plane (El=−1.7 deg.).

Figure 3: Calculated radiation patterns (26GHz, V-pol., only a contribution from current on the reflector is included.).

Figure 4: Prototype of the antenna.



(a) Vertical plane (Az=0 deg.).



(b) Horizontal plane (El=−1.7 deg.).

Figure 5: Measured radiation patterns (26.125GHz, V-pol.).