Synthesis of Shaped-Beam Reflectarray for Indoor WLAN access Point

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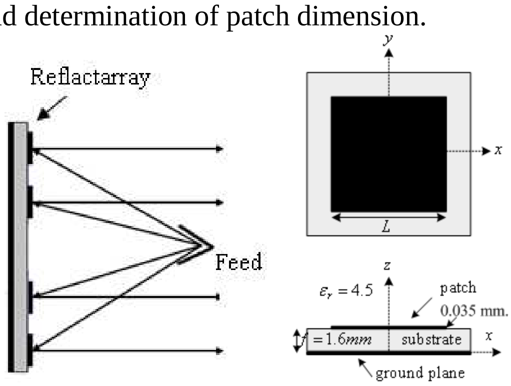
1. Introduction

At current stage, the antennas for WLAN access points are the linear dipole, slot array, and microstrip antenna, ect. [1-2]. These antennas are not suitable for field radiating in the large room and complex shaped room because of power loss in unnecessary directions. In many applications, reflectarray antenna requires radiation patterns to be shaped such that the pattern contour fits the shape of the desired coverage region [3] which the antenna is placed on the ceiling. The shaped contour radiation pattern reduces wasted transmitted power by minimizing the illumination of unwanted areas such as out of the room. The advance of the reflectarray antenna is low profile and light weight to easier placement and deployment on the WLAN indoor [4]. This paper will present the synthesis and simulation results of reflectarray. The physical optics(PO) [5] and optimization method are employed for reflector surface shaping to produce the desired contoured beam.

2. Reflectarray Design

Even though, the almost reflectarray antenna has the flat surface, but its principle operation likes as the reflector antenna. In this paper, the synthesis of shape-beam reflectarray for indoor WLAN access points will be presented. Once the phase required for the reflection coefficient at each reflectarray element has been determined, the dimensions of the printed patches have to be adjusted for matching to that phase. In addition, a single layer configuration is shown in Fig.1 and the design of a reflectarray with the desired features is summarized in the Table1. The coverage requirements for the reflectarray antenna and the performances are actually achieved by the baseline design using the grided shaped reflector that is directivity at edge coverage 20 dB. The design stage consists of three parts that are determining the reference curve surface using radiation pattern specification synthesis, translating the desired aperture phase to be the patch reflectarray phases, and determination of patch dimension.



Unit cell

(a) (b)

Figure 1: The Geometry of Microstrip Reflectarray.

Table 1: Reflectarray Data.

Design frequency (GHz)	5.8
Reflectarray diameter (cm)	(35x35)
Number of elements	361
Period (cm)	2.06
Feed position (cm)	(0,0,12)
Gain requirement(dB)	20
Radiation pattern specification	Rectangular

2.1 Calculation reference curve surface

The reference curve surface is calculated from (1), which can be achieved by the use of all the optimized coefficients of the Polynomial Fourier Series (PFS), that obtains the desired radiation pattern. Physical optics (PO) is employed in the synthesis stage to calculate the accurate far field pattern. The reference shape is controlled by coefficients in (1) and these can be varied so that the gain of the antenna conforms to that specifies at the sample points. The 5.8 GHz reflectarray will be designed with the aperture size and coverage specification as a reference curve surface that was designed to illuminate room with a shaped coverage pattern.

$$z_r(x_r, y_r) = a_1 x_r + a_2 x_r^2 + a_3 x_r^3 + a_4 y_r + a_5 y_r^2 + a_6 y_r^3 + a_7 x_r y_r + a_8 x_r y_r^2 + a_9 y_r x_r^2 + \sum_{m=1}^{N_x} \sum_{n=1}^{N_y} C_{mn} f_m(x) f_n(y) \quad (1)$$

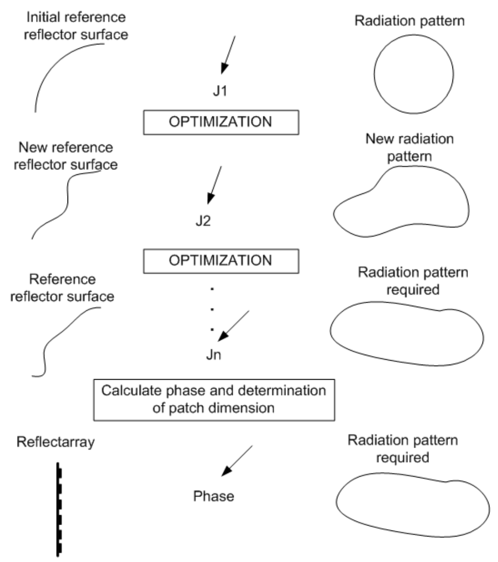


Figure 2: Contour Beam Reflectarray Technique.

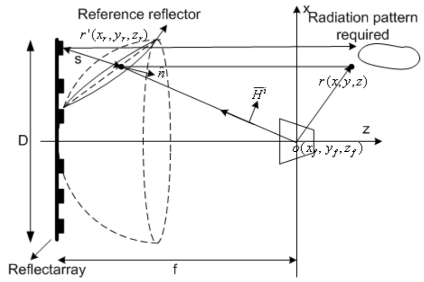


Figure 3: Geometry of the Surface Calculation.

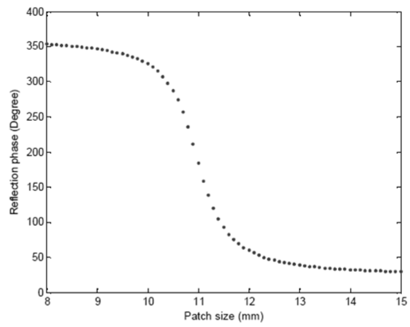


Figure 4: Phase of the Reflection Coefficient

For the reference surface synthesis as illustrated in Fig. 3, the PO expression for the electric fields radiated from the reference surface is given by

$$\overline{E}^{PO}(\overline{r}) = -j\omega\mu\left(\frac{e^{-jkr}}{4\pi r}\right)\int_{S_a} [J_s^{PO}(r') - (\hat{r}.J_s^{PO}(r')r)] e^{jkr'.r} \sqrt{\nabla^2{}_x + \nabla_y^2 + \nabla_z^2}\, ds \quad (2)$$

where

$$\nabla_x = -(a_1 + 2a_2 x_r + 3a_3 x_r{}^2 + a_7 y_r + a_8 y_r{}^2 + 2a_9 x_r y_r + \sum_{m=1}^{Nx}\sum_{n=1}^{Ny} C_{mn} f_n(y_r) \frac{df_m(x_r)}{dx_r}),$$

$$\nabla_y = -(a_4 + 2a_5 y_r + 3a_6 y_r{}^2 + a_7 x_r + a_9 x_r{}^2 + 2a_8 x_r y_r + \sum_{m=1}^{Nx}\sum_{n=1}^{Ny} C_{mn} f_n(x_r) \frac{df_m(y_r)}{dy_r}),$$

$$\nabla_z = 1.$$

$J_s^{PO} = 2\hat{n} \times \overline{H}^i$ is the so-called surface electric current densities or equivalent surface current sources on S surface and $\hat{n}$ is the unit normal vector outward from the reflector surface. The calculation of the electrical field can be led to the antenna characteristics, namely, the radiation pattern and gain. The shaped beam are designed by the antenna characteristics for coverage area where is complicated.

Note that the normalization is such that the gain in dB_j of the j th element is given by

$$G_j^{PO}(\theta,\phi) = 10\log_{10}(|E_j^{PO}(\theta,\phi)|^2) \quad (3)$$

The gain G_j^{PO} of the antenna is calculated using PO currents on the reflector and are compared to the specified gains G_j^S called objective function (F) as shown in the equation below.

$$F(position, coefficient) = \sum_{position} \left| G^{PO} - G^{S} \right| \quad (4)$$

Fig. 2 shows the optimization method which is calculated by (5) [6]. The coefficients of the Polynomial Fourier Series are varied in a search to minimize. Minimizing of F is the criterion for the optimization procedure. The difference between the gain desired ($G_j^{\,S}$) and the gain achieved ($G_j^{\,PO}$) is minimized, when F is minimized. Then, the set of $\sqrt{\nabla^2{}_x + \nabla_y^2 + \nabla_z^2}$ is minimized.

$$f_1^{(k)} \le f_2^{(k)} \le \ldots \le f_{n+1}^{(k)} \quad (5)$$

where $f_i^{(k)}$ denote $f(F_i^{(k)}, z_{ri}^{(k)})$ and k is iteration, $k \ge 0$

2.2 Translating the desired aperture phase to be the patch reflectarray phases

The amount of phase requirement of array elements is simply obtained by comparing the configuration of a reference reflector with that of a flat microstrip reflectarray as shown in Fig. 3. The required phase-shift on the reflectarray is obtained from the distances between the plane and the reflector as calculated in (6).

$$\phi_j = 2k_0 z_r \,, \quad (6)$$

where k_0 is the wavenumber and z_r is the distance along the axis of the reflector from the focal point to the edge of the rim that is calculated from (1). For phase optimization, the set of phase ϕ_j that minimize F is sought.

2.3 Determination of patch dimension

To compensate a desired aperture phase above, the lengths of the patches are determined, element by element, using CST software as shown in Fig. 4. The routine takes into account the incidence angle of the impinging wave at each radiating element position and the dissipative losses introduced by the dielectric layers. The mutual coupling between elements is computed by the assumption of local periodicity.

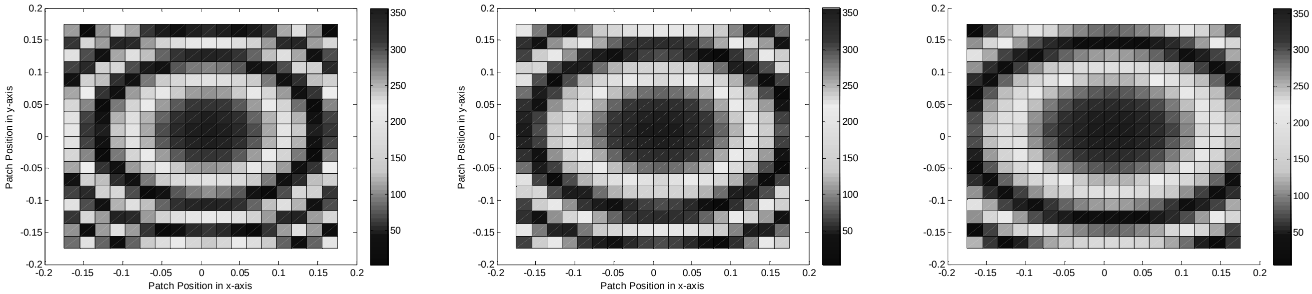
3. Simulation Results

The iterative technique outline shown in Fig. 2 was used to design radiation pattern requirement which the far-field points are 11 by 31 points rectangle grid. To begin the optimization, we are assigned the reference reflector using parabolic equation. The current is calculated using PO and the reference far-field radiation pattern as shown in Fig. 6(a). Then comparing between $G_j^{\,S}$ and $G_j^{\,PO}$ are called function objective. If the difference value of $G_j^{\,S}$ and $G_j^{\,PO}$ is a few. The radiation pattern is correcting. After that, the calculation phase and determination of patch dimension are determined as shown in Fig 5. The field on an aperture and radiated field in (*u*,*v*) coordinates can be calculated by the conventional array theory expressed by (7) where $u = \sin\theta\cos\phi$ and $v = \sin\theta\sin\phi$.

$$E(\hat{u}) = \sum_{m=1}^{M}\sum_{n=1}^{N} F(\vec{r}_{mn}\cdot\hat{a}_Z)\cdot A(\vec{r}_i\cdot\hat{u}_r)\cdot A(\hat{u}\cdot\hat{u}_r)\exp\left[-jk_0\left(\left|\vec{r}_{mn}\right| + \vec{r}_i\cdot\hat{u}\right) - j\Delta\phi_{mn}\right] \quad (7)$$

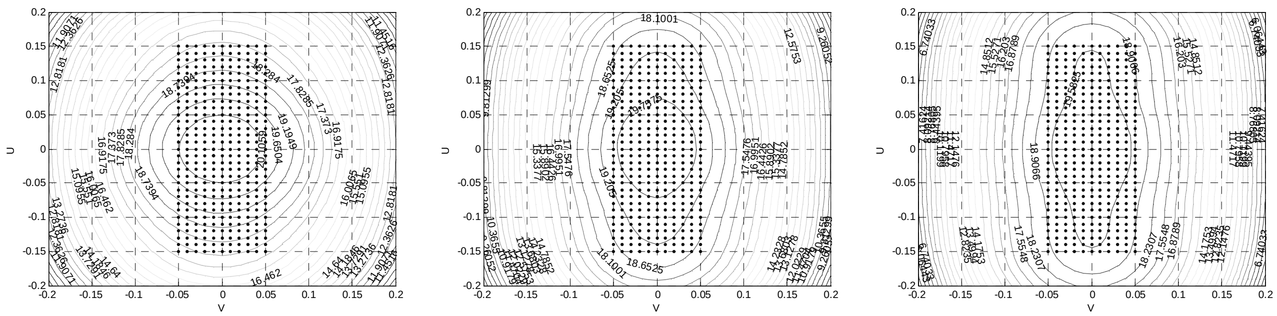
where F is the feed pattern function, A is the reflectarray element pattern function. $\hat{r}_i$ is the vector from center of reflectarray to *mn*-th element**.** $\hat{u}_r$ is the reflected field pointing direction. $\Delta\phi_{mn}$ is the required compensating phase of the *mn*-th element, respectively.

In this case, the field at the projected aperture is calculated at points of a regular periodic mesh along x_r and y_r directions. The far-field of feed has been considered and has been modeled through a $\cos^q$ function in order to determine the illumination levels on the reflectarray surface. Then, the optimization for the far-field pattern of reflectarray antenna at 670th iterations and the last iteration at 2640th as shown in Fig. 6(b) and Fig. 6(c), respectively. If, the far-field pattern did not change, so the iterative process was ended. The beam is compared with the requirements which are shown in Fig. 6, the general good agreement will be found. The coverage area is illuminated with the minimum desired gain of 19.58 dB, which is sufficient for the system requirements.



(a) The 374th iteration. (b) The 670th iteration. (c) The 2640th iteration.

Figure 5: Phase Distribution of the Reflectarray Element for Rectangle Coverage.



(a) The 374th iteration. (b) The 670th iteration. (c) The 2640th iteration.

Figure 6: The Iterative Technique for Far-Field Pattern of Reflectarray Antenna.

4. Conculsion

A method has been presented for synthesizing a reflectarray surface that accurately produces a shaped contour radiation pattern. The shaped reference curve is verified by physical optics. Another approach being studied is to optimize the coefficients of a set of function objective. The iterative technique outline in this paper (see Fig. 2.) can be use to arrive at an optimization reference reflector. Next, a phase-only pattern synthesis technique is applied to obtain the phase-shift distribution on the reflectarray surface requirement that produces the shaped pattern for the central beam. Then, the dimensions of the printed patches are adjusted to produce the required phase-shift at each element. Finally, the far-field generated by the feed is used to compute the radiation patterns of the reflectarray. The radiation patterns for beams exhibited a shaped beam close to the required service area.

References

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