Estimation of the enhanced scanning performance of triangular grid in cavity-backed microstrip array antenna

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Abstract: This paper presents the algorithm for analyzing the cavity-backed microstrip skewed infinite array whose radiation element consists of circular patch, probe feed, and cavity structure. Then the enhanced performance of triangular grid in cavity-backed microstrip array is estimated by comparing it with rectangular grid array. Finally, it is shown that triangular grid can reduce the scanning loss up to 38% in cavity-backed microstrip array.

1. Introduction

Microstrip antenna has been one of the most popular research topic in recent days, especially the advantage of flat, low profile, and array antenna design. But, for array applications, engineers have been suffered from the scan blindness, which is generated from surface wave in substrate. To resolve this problem, cavity-backed microstrip radiator was proposed.[1] In this paper, we presented the algorithm for analyzing cavity-backed microstrip skewed infinite array and, estimated the enhanced scanning performance of triangular grid in cavity-backed microstrip array.

2. Numerical analysis algorithm

The numerical analysis algorithm of MoM for solving cavity-backed microstrip radiator was proposed in reference[2], and the radiator structure was showed in Fig. 1. Then, we apply Floquet's theorem to solve the periodic structure of array, and we can obtain the spectral domain Green's function for rectangular grid array with some manipulations, as follows:

$$\tilde{G}_{xx}^{HM}(k_x, k_y, 0 \,|\, 0) = -\frac{1}{\omega\mu}\frac{(k_0^2 - k_x^2)}{k_z}$$

$$\tilde{G}_{yx}^{HM}(k_x, k_y, 0 \,|\, 0) = \tilde{G}_{xy}^{HM}(k_x, k_y, 0 \,|\, 0) = -\frac{1}{\omega\mu}\frac{k_x k_y}{k_z}$$

$$\tilde{G}_{yy}^{HM}(k_x, k_y, 0 \,|\, 0) = -\frac{1}{\omega\mu}\frac{(k_0^2 - k_y^2)}{k_z}$$

where, $k_z = \begin{cases} \sqrt{k_0^2 - \beta^2}, & k \ge \beta \\ j\sqrt{\beta^2 - k_0^2}, & k < \beta \end{cases}$

And, with some modification in propagation constants to compensate for skewed array structure[3], we obtain the Green's function for skewed infinite array as follows:

$$\vec{G}^{HM}(x,y,0\,|\,x_0,y_0,0)=\frac{1}{dxdy}\sum_{m=-\infty}^{+\infty}\sum_{n=-\infty}^{+\infty}\vec{G}^{HM}(-k_{x_m},k_{y_n},0\,|\,0)e^{-jk_{x_m}(x-x_0)}e^{-jk_{y_n}(y-y_0)}$$

$$where\quad k_{x_m}=k_0u+\frac{2\pi m}{dx}\quad and\quad k_{y_n}=k_0v+\frac{2\pi n}{dy}-\frac{2\pi m}{dx\tan\alpha}$$

Fig 3. shows the calculation results of ARC(Active Reflection Coefficient) in rectangular grid array and some reference values.[4][5] It can be seen that there is a good agreement showing the validity of our algorithm. It also shows that cavity-backed microstrip array avoids the scan blindness with comparison to the normal microstrip array having the scan blindness at the scan angle 45°. In this document, ARC is defined as:

$$ARC=\frac{Z_{in}(\theta,\phi)-Z_{in}(0,0)}{Z_{in}(\theta,\phi)+Z_{in}(0,0)}$$

3. Enhanced scanning performance of triangular grid in cavity-backed microstrip array

Fig. 4 shows the resonant frequency shift between single radiator and infinite array, and Fig. 5 shows the enhancement effect of triangular grid array. Geometry dimensions are listed in Table 1. It is known that the number of radiator in triangular grid array can be reduced to 85% to achieve the same performance of rectangular grid one.[6] In this figure, the calculated result shows that triangular grid is more efficient about 10~38% within the range of 40~60° scan angle. Fig. 6 shows the ARC variation in terms of the skew angle change, and it can be referred that the skew angle within range of 40~60° is the most efficient one. So we can conclude that triangular grid(skew angle of 60°) array is more efficient than rectangular grid(skew angle of 90°) at the point of scanning performance.

4. Conclusion

In this paper, we present the algorithm of analyzing skewed angle cavity-backed microstrip array. And the simulation results show that triangular grid array has the superior scanning performance than the rectangular grid one. Reflection coefficient of array shows the slight shift in comparison to single radiator. Finally, the calculated result shows that triangular grid is more efficient about 10~38% within the range of 40~60° scan angle than the rectangular grid one.

Reference

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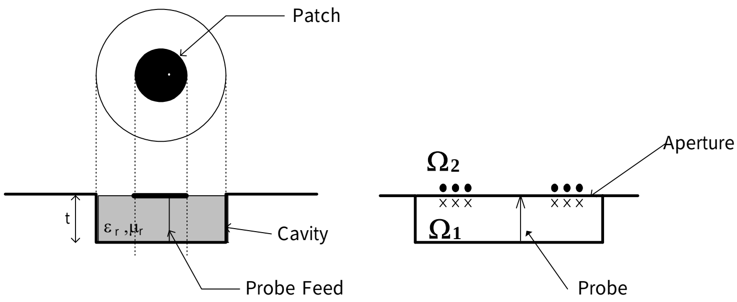
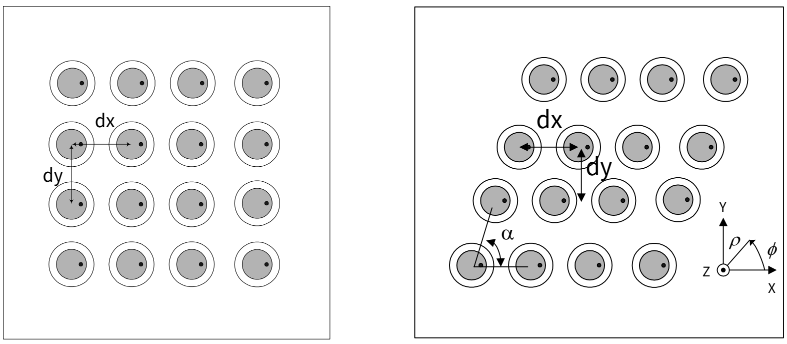


(a) (b)

Fig. 1 Cavity-backed microstrip radiator and its equivalent model for analysis



(a) (b)

Fig. 2 The structure of infinite cavity-backed microstrip array of (a) rectangular and (b) skewed array

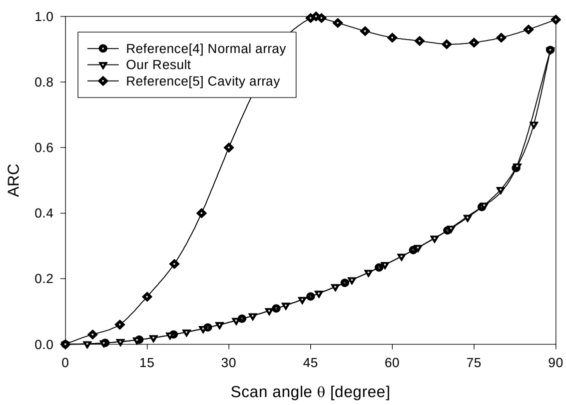


Fig. 3 Comparison of active reflection coefficient with other verified calculation results

radius of patch	0.57 *cm*	*dx*	1.84*cm*
radius of cavity	0.8 *cm*	*dy*	0.92(α=30°) ~1.78(α=75°) *cm*
ε_r	3.27	height of substrate	20 *mil.*
position of feed probe	matching position		

Table 1. Dimension of array geometry for simulation

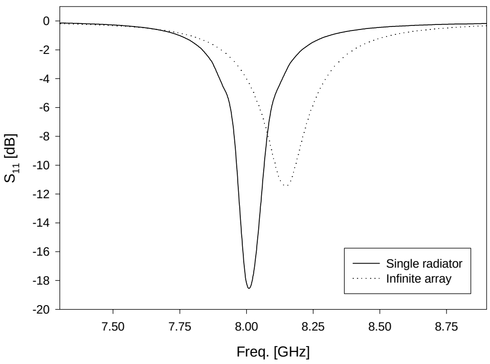


Fig 4. The calculated reflection coefficients of the cavity-backed microstrip infinite array

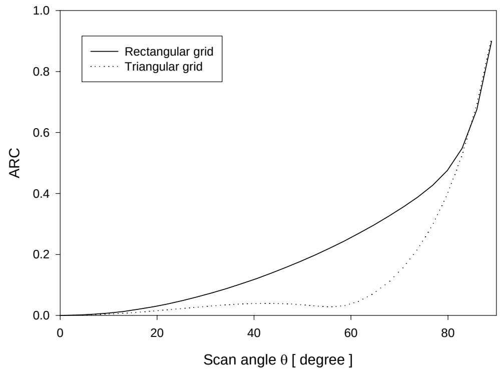


Fig 5. Active reflection coefficient of triangular and rectangular grid infinite arrays

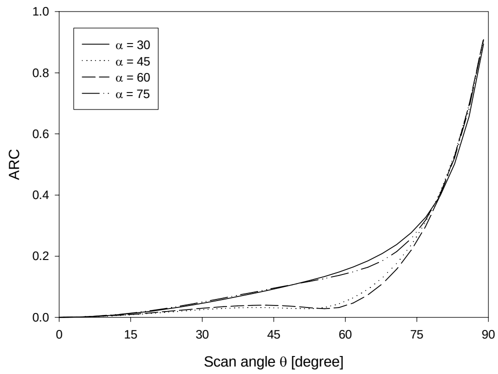


Fig. 6 Active reflection coefficient of infinite array in term of the skewed angle