A 2D Periodic Cross-Shaped Leaky-Wave Antenna

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***Abstract*— A 2D periodic leaky-wave antenna in the shape of a cross is described here. It consists of grounded dielectric substrate with narrow rectangular metal patches on the upper surface. The substrate and ground plane are formed in the shape of a cross. The structure is fed by a slot in the ground plane. This antenna can be optimized to produce a narrow and directive elliptical beam at broadside.**

I. Introduction

Two dimensional (2D) planar leaky wave antennas that have been extensively studied before were usually in the form of PRS (partially reflective surface) structures. The PRS 2D leaky wave antenna [1] radiates from the fundamental Floquet harmonic of the leaky wave. Here, the subject of study is a 2D periodic leaky wave antenna [2] which is different from a PRS/FSS structure in that it radiates from a higher-order leaky-wave Floquet harmonic.

A cross-shaped 2D periodic leaky-wave antenna that radiates from a higher-order Floquet harmonic is presented here. The antenna produces a directive elliptical beam at broadside, and is very simple in construction, using a slot in the ground plane as the feed.

II. Design of Cross-Shaped 2D Periodic LWA

The 2D periodic leaky wave antenna (LWA) was first theoretically analyzed as an infinite structure using the periodic spectral domain immittance (periodic SDI) method [2]. A section of the infinite structure is shown in Fig. 1. The antenna is fed by a y-directed slot in the ground plane that is modeled as a magnetic dipole, as shown in Fig. 1. This structure has a periodic distribution of patches on the top surface of the dielectric substrate. The narrow y-directed slot in the ground plane is centered at the location ($x_0 = -a/2$, $y_0 = 0$). This structure is optimized to produce maximum power density at broadside by adjusting a, the spacing between the patches along the x direction, while keeping all other parameters fixed. The spacing between the patches in the y direction, dimension b, can be either kept constant or chosen as a constant multiple of a. The infinite structure can be truncated along the x and y direction at a point where the power in the leaky wave has sufficiently reduced.

It was noted in [2] that the part of the structure that produces the main beam at broadside is concentrated in a narrow angular region along the x axis and the y axis radiating from the (-1, 0) and the (0, -1) Floquet harmonics, respectively. The rest of the structure contributes to producing grating lobes, which are undesirable. Therefore, the parts of the structure that do not contribute to the main beam are eliminated to form the 2D periodic leaky wave antenna in the shape of a cross shown in Fig. 2. It is expected that this antenna would retain the main beam characteristics without producing the undesirable grating lobes in the pattern.

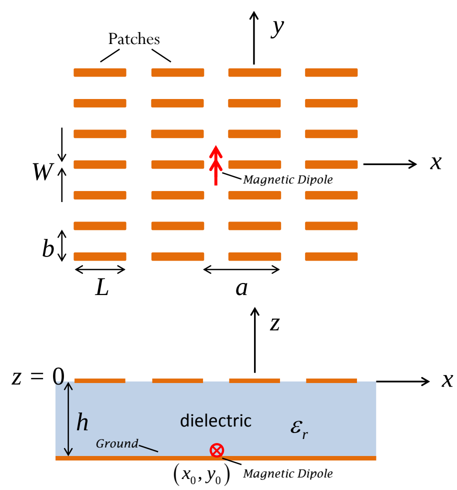

Fig. 1. A section of the infinite 2D periodic leaky wave antenna structure.

III. Pattern of a Cross-Shaped 2D Periodic LWA

The theoretical radiation pattern of the 2D periodic leaky-wave antenna of Fig. 1 can be calculated using the periodic SDI method for the infinite structure. The cross-shaped 2D periodic LWA (Fig. 2) is simulated with Ansys Designer, where the substrate and the ground plane are infinite, while there is a finite number of patches on the upper surface of the substrate, which extends 30.06 cm along x and 21.04 cm along y. Here the frequency of operation is 24 GHz, the substrate has a relative permittivity of $\varepsilon_r = 3.66$ and a loss tangent of $\tan \delta = 0.004$, and the substrate thickness is 0.762 mm. The length of each copper patch is $L = 0.31$ cm and the width is $W = L/5$. By optimizing this design for maximum power density at broadside, we obtain the dimensions of the unit cell as a =

1.1441 cm for $b = a/1.2$. The radiation patterns obtained for the infinite 2D periodic LWA from theory, and the patterns of a finite and the cross-shaped 2D periodic LWA from simulation in Ansys Designer are given in Fig. 3 ($\phi = 0^o$), Fig. 4 ($\phi = 90^o$) and Fig. 5 ($\phi = 45^o$).

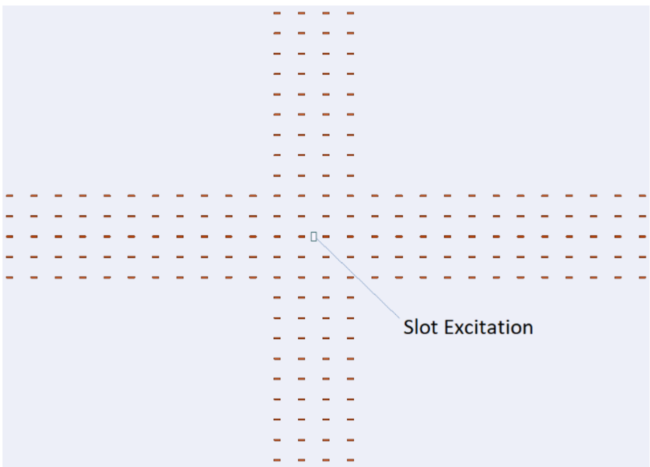

Fig. 2. The cross-shaped 2D periodic leaky-wave antenna fed by a slot in the ground plane.

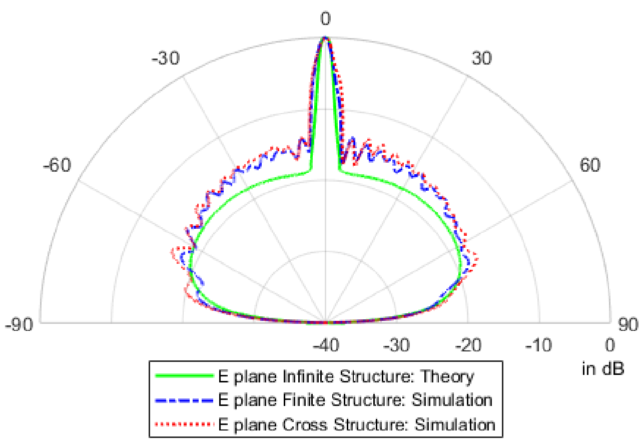

Fig. 3. Normalized E-plane patterns ($\phi = 0^o$) from theory and simulation for the finite and cross-shaped 2D periodic LWA.

From Figs. 4, 5 and 6, it becomes clear that the radiation patterns of the infinite 2D periodic LWA, the finite 2D periodic LWA, and the cross-shaped 2D periodic LWA has the same directive main lobe with the same beamwidth. The grating lobes of the infinite structure in Fig. 5 are significantly reduced for the finite structure and are completely eliminated for the cross-shaped structure.

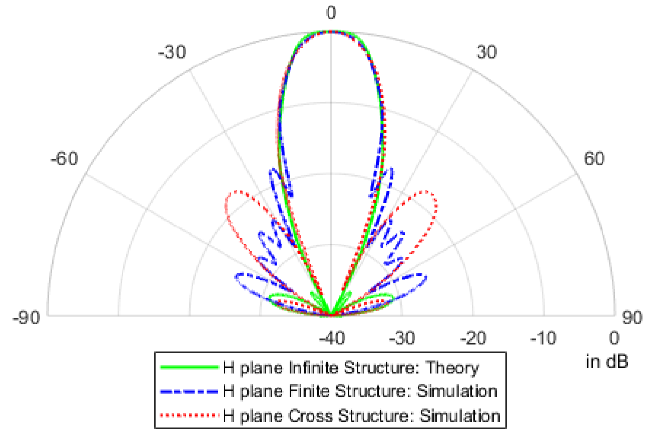

Fig. 4 Normalized H-plane patterns ($\phi = 90^o$) from theory and simulation for the finite and cross-shaped 2D periodic LWA.

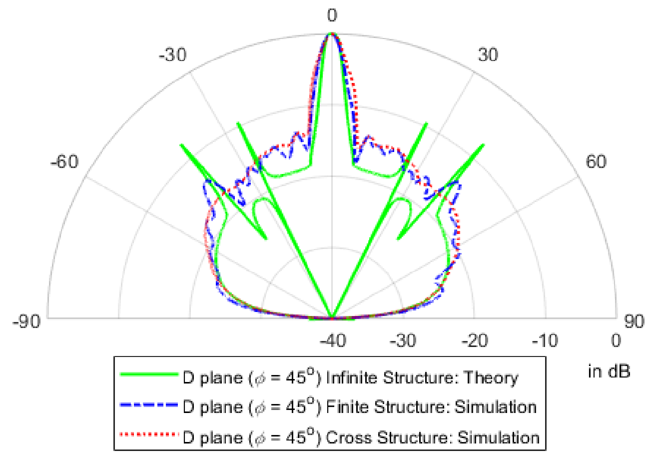

Fig. 5 Normalized radiation patterns in the D plane ($\phi = 45^o$) from Theory and simulation of the finite and cross-shaped 2D periodic LWA.

Conclusions

It has been found that a finite-sized 2D periodic cross-shaped leaky-wave antenna produces a very similar main beam radiation pattern as that of a finite-sized 2D periodic leaky-wave antenna as well as an infinite 2D periodic leaky-wave antenna. However, the cross-shaped 2D periodic LWA reduces the grating lobes in the pattern and results in an overall area reduction due to the shape of the cross.

References

[1] G. V. Trentini, "Partially reflecting sheet arrays," *IEEE Transactions on Antennas and Propagation*, vol. 4, pp. 666-671, Oct. 1956.

[2] S. Sengupta, D. R. Jackson, S.A. Long, "Modal analysis and propagation characteristics of leaky waves on a 2D periodic leaky-wave antenna," *IEEE Transactions on Microwave Theory and Techniques*, vol. 66, no. 3, pp. 1181-1191, Mar. 2018.