Design Procedure for 2D Slotted Waveguide Antenna with Controllable Sidelobe Level

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***Abstract*—This paper presents an inventive and simple procedure for the design of a 2D slotted waveguide antenna (SWA) having a desired sidelobe level (SLL) and a pencil shape pattern. The 2D array is formed by a defined number of 1D broadwall SWAs, which are fed using an extra broadwall SWA. For specified number of identical longitudinal slots in both dimensions, the desired SLL and the required operating frequency, this procedure finds the slots length, width, locations along the length of the waveguide, and offsets from its centerline. This is done for the radiating SWAs as well as the feed SWA. An example SWA with 8×8 elliptical slots is designed using this procedure for an SLL lower than -20 dB, where the design results are also reported in this paper.**

I. Introduction

Slotted Waveguide Antennas (SWAs) radiate energy through slots cut in a broad or narrow wall of a rectangular waveguide. Their advantages include relatively low weight and small volume, simple design, a high power handling, high efficiency, and good reflection coefficient [1]. SWAs can be resonant (standing wave) or non-resonant (traveling wave). Resonant SWAs outperform the non-resonant SWAs in terms of efficiency due to its termination with a short circuit, compared to matching load in the case of the latter, but with a narrower bandwidth. The design of a resonant SWA has been introduced by Elliott [2]. Computing the length of each slot and offset has been mainly based on the graphs produced by Stegen in [3], or on numerical techniques.

In this paper a two-dimensional (2D) SWA array is designed for a pattern with a desired sidelobe level (SLL). It consists of multiple branchline waveguides with broadwall radiating shunt slots. A main waveguide is used in a novel way to feed the branch waveguides through a series of coupling slots. The conventional feeding mechanism is based on the use of inclined broadwall coupling slots [4]. A second mechanism employs inclined or non-inclined slots in the narrow wall [5], [6]. For the procedure presented in this paper, longitudinal broadwall slots are used for the feeding.

To explain the controllable-sidelobe 2D SWA design procedure, an 8×8 SWA is taken as an example. Using the steps presented by the authors in [7] for the 1D SWA case, this paper starts with the design of an 8-element 1D SWA with the same desired SLL. Eight identical such SWAs are required for the 2D SWA, where they are attached side by side. The proper design of the 1D SWAs ensures having the desired SLL in one principal plane. To enforce the same SLL over the whole 3D pattern, special care should be given to the design of the feed SWA, whose slots should power the radiating SWAs according to a correct distribution. For the taken example, the feed SWA should have 8 slots, separated consecutively by a distance related to the radiating SWA aperture width and wall thickness. Since this distance can be different from a half-guide wavelength, additional steps are taken to design the feed SWA using the procedure in [7], but without added complexity. Elliptical slots are used in the example since they are more robust for high-power applications.

II. Design Procedure

The complete SWA system consists of 8 branchline SWAs, each with 8 broadwall radiating shunt slots, and an 8-slot feed SWA. All SWAs, main and branchlines, are designed to have a minimum SLR value of 20 dB, using the procedure in [7]. The design is done for the 3.952 GHz frequency to ensure the branchline SWAs have each a total length of 50 cm.

A. Branchline SWAs Design

WR-229 waveguides ($a = 2.29$ in, $b = 1.15$ in) are used for the branchline SWAs. The 8 slots are distributed as follows: the center of the first slot and the last slot are placed at a distance of quarter guide wavelength ($\lambda_g/4$), or $3\lambda_g/4$, from the the waveguide feed and the waveguide short-circuited side respectively; and the distance between the centers of two consecutive slots is $\lambda_g/2$. The calculated slots displacements for each SWA branch using the procedure described by the authors in [7] from a Chebyshev taper in an alternating order are in mm: 4.26, 6.72, 8.88, 10.15, 10.15, 8.88, 6.72, and 4.26. The length of the elliptical slot, optimized to obtain a low reflection coefficient S_{11} at 3.952 GHz, is found to be 41 mm. The slot width is equal to 4 mm. According to the used antenna orientation, each branchline SWA has a broadside SWA in the azimuth plane, and an SLR higher than 20 dB in the elevation plane.

B. Feed SWA Design

The main SWA has to be designed to feed the branchline SWAs with a power distribution that results in an SLR not lower than 20 dB in the azimuth plane. The feed SWA is designed in a similar way to the radiating SWAs, with 8 elliptical slots made to the broadwall. The major difference is the spacing between the slots. To position each slot at the center of each branchline SWA, the distance between neighboring feed slots is equal to $a + 2w$, where w is the branch waveguide wall thickness. This is different from the conventional $\lambda_g/2$ distance assumed in [2] and [7], and would affect the operating frequency of the feed SWA if not addressed properly.

To overcome this issue, the waveguide dimensions for the feed SWA should be selected such that half the guide wavelength of the feed SWA is as close as possible to $a+2w$ of the branches, or $\lambda_{g(feed)} \simeq 2 \times (a_{branch} + 2w_{branch})$. For this example, $a_{branch} + 2w_{branch} = 62.23$ mm, and the closest standard waveguide having $\lambda_{g(feed)}/2 \simeq 62.23$ mm is the WR-187 waveguide, with $\lambda_{g(feed)}/2 = 62.96$ mm. If standard waveguide dimensions do not provide a satisfactory solution, non-standard ones (for the feed or even the branchline SWAs) should be used. The length of the required WR-187 feed waveguide is 624.5 mm. The corresponding slots displacements calculated by the authors in [7] from a Chebyshev taper in an alternating order are in mm: 1.88, 2.93, 3.84, 4.349, 4.349, 3.84, 2.93, and 1.88. The width of the elliptical slots of the feed is 3.3 mm. The optimal length for the standalone feed SWA for resonance at 3.952 GHz is 41.7 mm.

C. 2D SWA

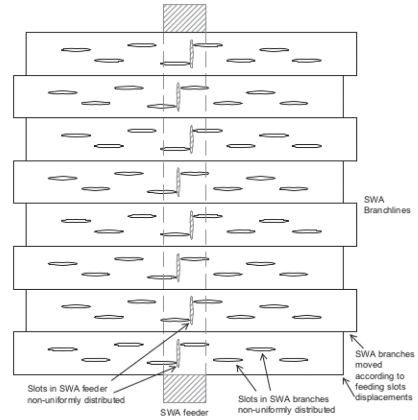
The feed SWA is integrated with the branch SWAs by having identical slots cut into the back broadwall of each branch SWA to coincide with the feed slot. The combined SWA system is shown in Fig. 1(a). Since the feed slots have different displacements from the feed waveguide centerline, and in order to have each at the exact middle of the back broadwall of the corresponding branch SWA (equidistant from slots 4 and 5), each branch SWA is moved according to the displacement of its own feed slot.

III. Simulations and Results

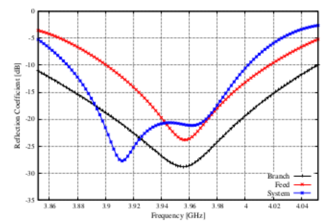
The design is simulated with the parameters listed in the previous section. Fig. 1(b) shows the reflection coefficient (S_{11}) of the branch, feed, and the 2D SWAs. The gain pattern plots of a 1D SWA and the complete 2D are given in Fig. 2. Comparing the 1D and 2D cases, the HPBW in the azimuth plane has decreased from $78°$ to $8.8°$ in the azimuth plane, and the total gain has increased from 15.3 dB to 24 dB. The SLL for the 2D SWA is -20 dB in the azimuth plane, and -23.5 dB in the elevation plane.

IV. Conclusion

This paper presented a simple procedure for the design of 2D slotted waveguide antenna arrays with desired SLLs. Multiple SWA branches are used as radiating antennas, with a main SWA used in a novel way as the feed. The procedure was explained through the example design of an 8×8-elliptical-slot SWA with SLL lower than -20 dB.

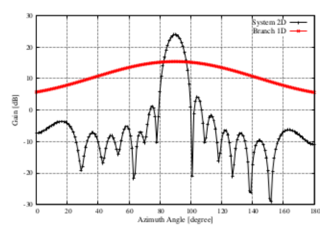


(a)

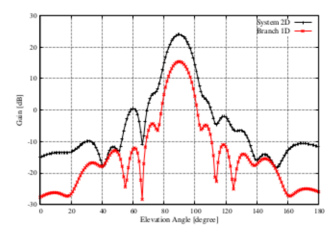


(b)

Fig. 1. (a) Design of 2D SWA, (b) S_{11} for the branch, feed, and 2D SWAs.



(a) Azimuth



(b) Elevation

Fig. 2. Rectangular gain pattern comparison of 1D and 2D SWAs, (a) azimuth plane, (b) elevation plane.

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