Cavity Backed Slot Antenna Fed by New Groove Gap Waveguide Structure

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***Abstract* — In this work, a cavity backed slot antenna fed by a new gap waveguide structure is introduced. Instead of using conventional pins, the proposed structure consists of an air groove surrounded by λ/8 (half-height) pins located above a metal wall of λ/8 high on each side. Unlike previous pins forms, which need at least two rows of pins on each side of the guiding channel, only one row of the proposed form is sufficient to prevent wave leakage. To validate the new proposed configuration, the dispersion diagram of a unit cell is investigated and the stopband 4–12 GHz is confirmed. Then, a cavity backed slot antenna is designed by cutting a window at the end of the guiding structure. The resonant frequency of this antenna is 9.94 GHz. This antenna is fabricated using brass CNC milling technology. The simulated and measured reflection coefficients and radiation patterns of the proposed antenna are in good agreement.**

***Keywords* — cavity backed slot antenna, groove gap waveguide, pins from, sidewalls.**

I. Introduction

In the last decade, a new transmission structure, the so-called gap waveguide, has been proposed. A series of components based on this technology, such as power dividers, filters, couplers, and antennas, has been designed and verified experimentally [1]-[7]. Basically, the gap waveguides have been realized until now by two parallel metal plates, with periodic metal pins on the lower plate to play the role of an artificial magnetic conductor (AMC) and smooth surface on the upper plate as a perfect electric conductor (PEC). In such guiding structures, very little electromagnetic waves can propagate through the pin texture, except along some guiding configurations, such as ridges in ridged gap waveguides [8], microstrip lines in inverted microstrip line gap waveguides [9], or grooves in groove gap waveguides [10], under the condition that the gap between the top of the pins and the upper plate is much less than quarter wavelength. On the one hand, the gap waveguides have the advantage of lower loss compared with planer technologies such as microstrip lines and substrate integrated waveguides. In gap waveguides, the electromagnetic waves are constrained in the air between the parallel plates with no dielectric loss. On the other hand, the gap waveguides were proposed as an alternative to conventional metal-pipe rectangular waveguides, as the requirement for conductive contact between the two parallel plates is not stringent.

In previous designs, different pins forms have been introduced. Half-height-pin form is proposed for reducing the fabrication cost [11]. In this from, the full-height conventional pins on one of the two parallel plates are divided into two half-height pins placed on the two parallel plates. However, that increases the number of the pins to the double which leads to double the manufacturing time. Also recently, interdigital-pin bed of nails has been proposed [12]. The metal pins are allocated to the two plates alternatively, where each pin is surrounded by four pins of the other plate. The advantage of the interdigital-pin lattice is that a minimum pin gap could be achieved, reducing the diameter of the milling cutter to its radius. This makes it possible to manufacture EBG structures operating at higher frequencies using the same machining center. However, in this configuration, the pins are quite long and thin, which poses a difficulty for low-cost manufacturing.

In this work, a new gap waveguide structure is introduced. The proposed structure consists of an air groove surrounded by one row of λ/8 (half-height) pins located above a metal wall of λ/8 high on each side, where λ is the wavelength of the cut-off frequency. This form of pins has great advantages over previous forms. In terms of manufacture, the proposed form has the lowest number of half-height pins where pins will be required only on the lower plate, not on both plates such as in [11]. The other advantage is that, by making use of the λ/8 high metal wall, a horizontal slot can be created at the end of the cavity to be used for signal radiation. To the best of the authors' knowledge, this is the first time that the sidewalls of gap waveguide technology can be used for signal radiation.

This paper is organized as follows: Section II describes the proposed gap waveguide structure, including the unit cell of proposed groove gap waveguide and its dispersion diagram and the cavity backed slot antenna structure. Section III demonstrates the antenna prototypes and shows simulated and measured results. Finally, Section IV provides the conclusion.

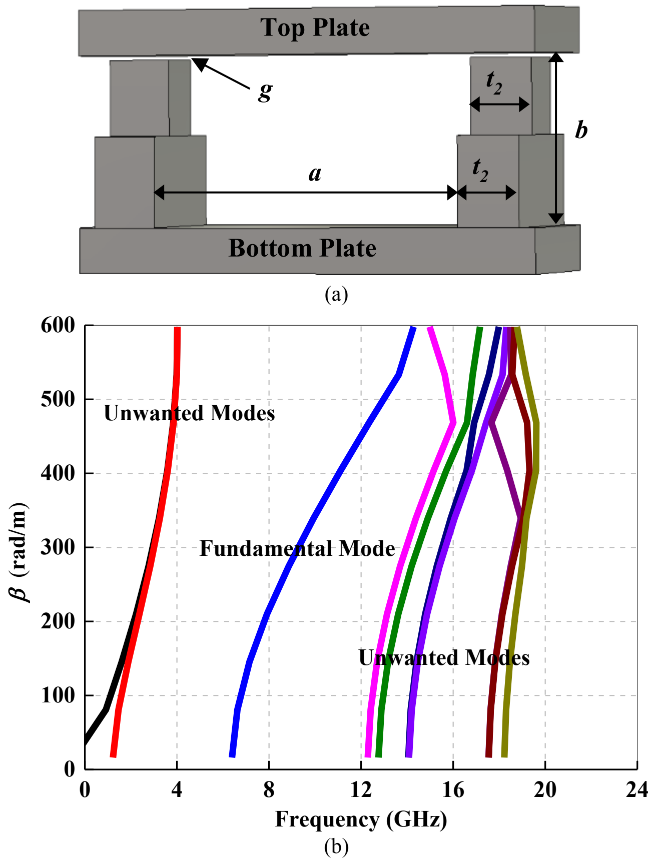

Fig. 1. (a) The unit cell of the proposed groove gap waveguide structure; (b) The dispersion diagram of the unit cell.

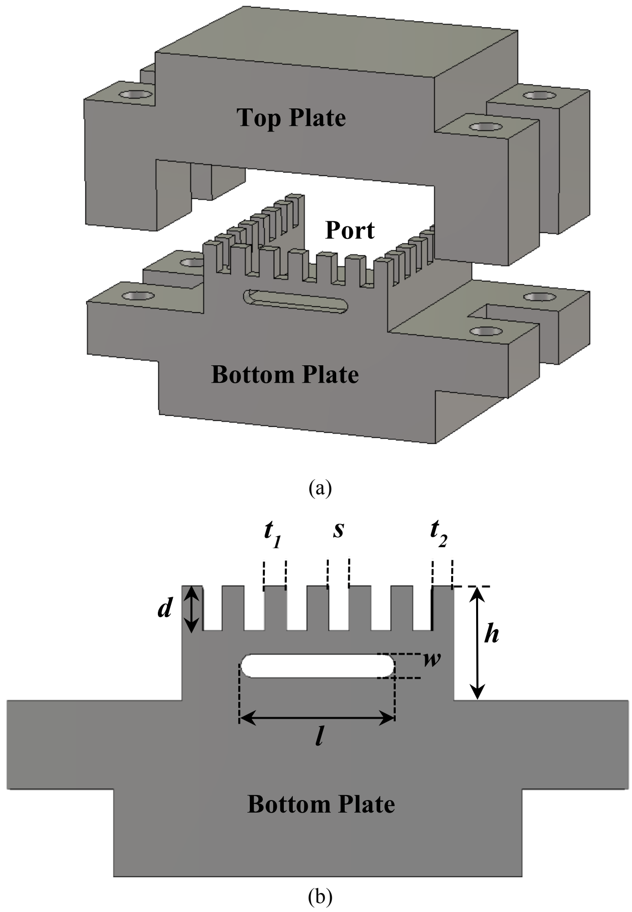

Fig. 2. The proposed cavity backed slot antenna. (a) 3-D view; (b) Front view of the bottom plate with dimensions.

II. The Proposed Gap Waveguide Structure

A. Unit Cell

A unit cell, consisting of an air groove surrounded by just one row of λ/8 high pins placed above a λ/8 high metal wall on each side, is shown in Fig. 1a. The dispersion diagram of this unit cell is obtained by using the Eigenmode solver of CST MICROWAVE STUDIO® [13] with the periodic boundary condition in the direction of propagation and perfect magnetic condition in the lateral directions. The new lateral pins form, with a gap (*g*) much less than λ/4 between the top of pins and the upper plate, can create a stopband as shown in Fig. 1b. A single mode, which is the dominant mode of this structure, propagates between the two parallel plates similar to that in a conventional rectangular waveguides within the obtained stopband. In this case, it covers the frequency band 4–12 GHz.

B. Cavity Backed Slot Antenna

To demonstrate the usefulness of the proposed structure, Fig. 2 shows the design of a cavity backed slot antenna. A feeding port is placed at one side of the cavity while a slot is placed at the opposite side. The gap waveguide section is used as a feeding structure. The proposed groove gap waveguide structure consists of an air groove with just one row of λ/8 high pins placed above a λ/8 metal wall, instead of conventional λ/4 full-height pins.

Table 1. Optimized parameters of the proposed cavity backed slot antenna. (Unit: mm).

Parameter	***a***	***b***	***g***	***d***	***h***
Value	22.86	10.16	0.3	5.14	10.16
Parameter	***l***	***w***	***s***	t_1	t_2
Value	15.25	2.00	2.00	2.17	2.00

It can be seen that the slot is etched at the centre of the metal wall under the half-height pins. This slot can be used for radiation. The slot length is equal to $\lambda_o/2$ and the slot width is $<\lambda_o/10$, where λ_o is the wavelength of the resonant frequency. The thickness of the slot is the same as the metal wall. The width of the cavity is kept similar to the width of the excitation port which is λ/2. The cavity depth in the propagation direction is chosen to be a full wavelength λ_o. In Fig. 2a, the upper plate is raised to show details of the lower plate. Dimensions of the proposed structure and slot, as shown in Fig. 2b, are chosen to give a resonance at 9.94 GHz. It is noteworthy that the boundary conditions of the structure are chosen open (with space) from all the sides. The optimized parameters of the proposed cavity backed slot antenna are shown in Table 1.

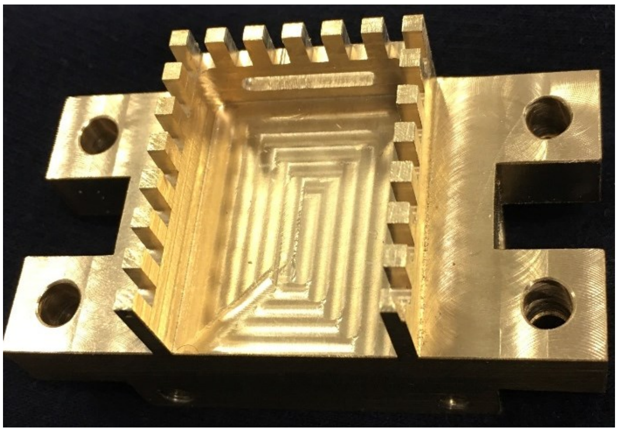

Fig. 3. Photograph of the proposed cavity backed slot antenna based on the new gap waveguide structure.

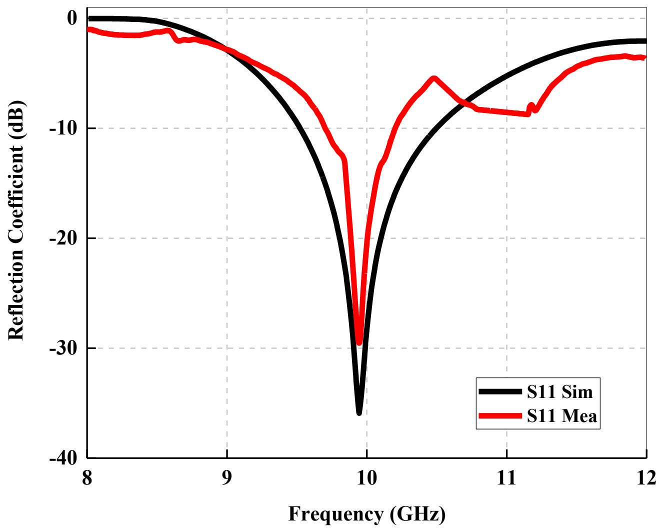

Fig. 4. Simulated and measured reflection coefficient $|S_{11}|$ of the proposed cavity backed slot antenna.

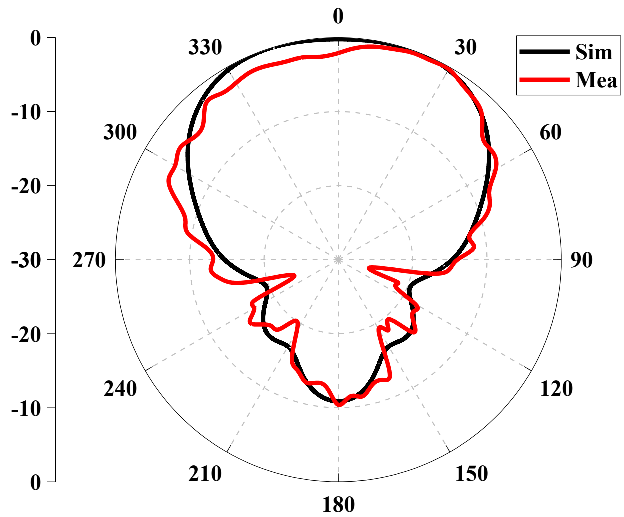

Fig. 5. Simulated and measured normalized radiation pattern of the proposed cavity backed slot antenna at 9.74 GHz.

III. Simulations and Measurements

Full-wave electromagnetic simulation was carried out using CST MICROWAVE STUDIO®. The whole structure of the optimized cavity backed slot antenna is shown in Fig. 2 . The metal was modelled as brass. Fig. 3 depicts the cavity backed slot antenna prototype, which is fabricated using brass CNC milling technology. The prototype cavity backed slot antenna was measured using an Anritsu 37369A vector network analyzer (VNA) with standard WR-90 waveguide flange interfaces. A Thru-Reflect-Line (TRL) calibration was first performed to calibrate the VNA and the cables. The simulated and measured reflection coefficients of the proposed antenna are shown in Fig. 4. The measured $|S_{11}|$ of the proposed antenna is in good agreement with the simulated one. For better comparison, the measured $|S_{11}|$ is coincided with the simulated one. The actual noticed frequency deviation is 0.2 GHz lower than the predicted frequency. The measured radiation pattern is also in good agreement with the simulated one as shown in Fig. 5. The mismatching between the simulated and measured results is mainly due to the manufacturing error. Nevertheless, it should be noted the results was obtained after first fabrication and no tuning was needed to achieve these measured results.

IV. Conclusion

A cavity backed slot antenna based on a new gap waveguide structure has been designed, fabricated and tested. This antenna is fabricated using brass CNC milling technology. To the best of the authors' knowledge, this is the first time that the sidewalls of gap waveguide technology can be used for signal radiation. The dispersion diagram of the unit cell of the new configuration has been investigated and the stopband has been confirmed. The measured results of are in good agreement with the simulation.

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