A Composite EBG Resonator Antenna with a Sparse Array Feed

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***Abstract*—In this paper, we study performance of a simple electromagnetic band gap (EBG) resonator antenna (ERA) that has a composite all-dielectric superstructure and is excited by a small sparse array. The cavity of the antenna is excited by a 2x2 array of waveguide fed slots with an inter-element spacing of 1.8λ_0. The ERA exhibits high gain with an excellent directivity bandwidth of around 20%. The proposed configuration provides improved performance in terms of antenna gain and directivity bandwidth, while significantly minimizing design complexity. Numerical results are presented and a peak gain of 21 dBi is demonstrated.**

I. Introduction

Utilization of electromagnetic bandgap (EBG) structure as an antenna superstrates has become an attractive solution to enhance the peak gain of simple antennas. EBG resonator antennas (ERAs) are also known as Fabry-Perot cavity (FPC) antennas, 2D leaky waves antennas and resonant cavity antennas. Some promising features of ERA are: highly directional radiation patterns, structure simplicity and low cost. Because of these attractive features, ERAs have become a promising candidate for microwave and millimeter wave applications. The classic ERAs are constructed by placing a superstructure about half a wavelength above a ground plane, forming a cavity between them. It's feed antenna can either be a single element or an array.

Initially, this concept was introduced in [1]. Later, various EBG resonator antennas with different superstructures which are periodic in 1-D [2-3], 2-D [4] and 3-D [5], have been proposed. Unfortunately, the small radiation bandwidth of these types of antennas have limited applications.

Hence, achieving high gain and wide directivity bandwidth while maintaining compactness is very desirable. Multi-layer EBG superstructures with dielectric constrast in axial direction have been designed to significantly enhance the 3 dB directivity bandwidth of ERAs [6]. Using a superstructure of three dielectric slabs, a peak gain of 18 dBi with 21.2% directivity bandwidth has been achieved.

In this paper, we study the performance of a composite ERA (CERA) with a sparse array feed. Our main objective is to reduce design complexity while achieving excellent performance in terms of peak gain and directivity bandwidth. In addition to this, we study the effects of sparse array inter-slot distance on the peak gain and directivity bandwidth of ERA. Previously, a multi-layer superstructure has been used along with an array of sources to enhance both the peak directivity and radiation bandwidth [7]. In that ERA, a peak gain of 22.7 dBi and a directivity bandwidth of 13.2% has been achieved. The total footprint of that ERA is 6λ_0 x 6λ_0. Also, a sparse array feed antenna has been used as an ERA [8].

It is shown in this paper that by utilizing a sparse array feedin the ERA in [6], a higher gain can be achieved while using small footprint. The resulting ERA has a peak gain of 21 dBi with 20.3% directivity bandwidth when the inter-slot distance D is 50 mm. Each slot is fed by a WR-75 waveguide. The total footprint of ERA is 4.7λ_0 x 4.7λ_0.

II. Configuration of The CERA

The configuration of the CERA, excited by a 2 x 2 sparse array, is shown in Fig. 1. The design procedure and unit cell analysis of this superstructure is described in [6]. This superstructure consists of three rectangular slabs of thicknesses t_1 = 3.175 mm, t_2 = 1.27 mm and t_3 = 3.175 mm and permittivity values of ϵ_1 = 3.27 , ϵ_2 = 1.27 and ϵ_3 = 4.5 respectively. The antenna is designed at f = 11.1 GHz with a cavity height (h) of 13.5 mm and an air gap (h_1) of 6.34 mm as shown in Fig. 1.

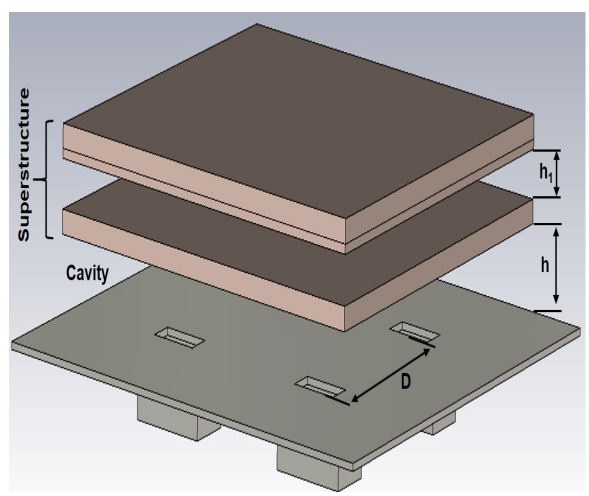

Fig. 1: The configuration of CERA. The cavity is excited by a 2 x 2 slot array. The supersructure has a footprint of 3.7λ_0 x 3.7λ_0 and the spacing between sparse array slots (D) is 50 mm.

For the ERA shown in Fig. 1, the superstructue and the ground plane are rectangular in shape with dimensions of $3.7\lambda_0$ x $3.7\lambda_0$ and $4.7\lambda_0$ x $4.7\lambda_0$, respectively. The sparse array is used to feed this composite superstrate. In this feed, slots are placed in the conducting plate with an inter-slot distance of 50 mm. These slots are fed by WR-75 waveguides.

III. Numerical Results and Discussion

CST Microwave Studio is used to study the performance of the CERA fed by the sparse array. Fig. 2 shows the broadside directivity of the same CERA fed by single slot feed. This ERA has a peak gain of 18 dBi. Its 21% radiation bandwidth extends from 11-13.35 GHz. The computed broadside directivity of the CERA fed by slot array is also shown in Fig. 2. This CERA has a peak gain of 21 dBi and directivity bandwidth of 20.25%, when the inter-slot distance is 50 mm. It is found that sparse array feed improves the peak gain by about 3 dBi while maintaining the 3 dB directivity bandwidth. The effect of the size of the ground plane is also shown in Fig. 2. It is noted that the CERA with $4.7\lambda_0$ x $4.7\lambda_0$ ground plane performs better than the CERA with the smaller $3.7\lambda_0$ x $3.7\lambda_0$ ground plane.

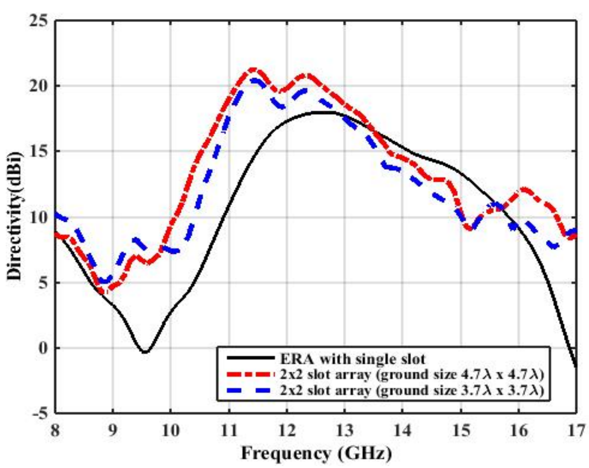

Fig. 2: Comparison between the broadside directivity of CERA fed by sparse array with the broadside directivity of CERA fed by single slot. The broadside directivity of a CERA with a smaller ground plane, which has the same area of the superstructure is also shown

Fig. 3 compares the broadside directivity of the CERA with the sparse 2x2 array feed (described above) with the broadside directivity of a previous ERA fed by 4x8 slot array feed [7]. The ERA with 4x8 slot array has a 13% radiation bandwidth with a peak gain of 22.7 dBi . It shows that the CERA fed by sparse array feed, has 56% more bandwidth than the previous ERA, despite the smaller footprint area. In addition to this, all feeds are well matched over the entire operating band.

After comparing the performance of CERA with two ERA's configurations, it is found that CERA outperforms the ERA fed by single slot in term of peak gain and ERA fed by 4 x 8 slot array feed in terms of radiation bandwidth.

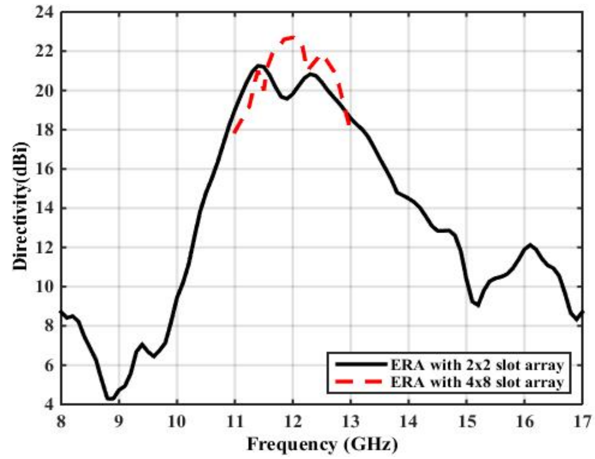

Fig. 3: Comparison between the broadside directivity of the CERA fed by 2x2 sparse array with the broadside directivity of a previous ERA fed by non-sparse 4x8 slot array.

IV. Conclusion

The characteristics a 2 x 2 sparse slot array feed are studied. The performance of this CERA is compared with ERA fed by single slot feed and a previous ERA fed by 4x8 slot array feed. It is found that the peak gain of the CERA is 3 dBi more than the peak gain of the ERA fed by single slot feed. It is also shown that the radiation bandwidth of the CERA is 56% more than the radiation bandwidth of the previous ERA fed by a non-sparse 4x8 slot array feed.

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