A Broadband Bow-Tie Cavity-Backed Slot for Traveling-Wave Arrays in the Millimeter-Wave Band

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***Abstract*—The use of bow-tie geometries to enhance the characteristics of a radiating element previously proposed by the authors is presented. The previous element consisted of a broadband cavity-backed slot in transmission configuration. The bow-tie shape of the cavity improves the bandwidth of the element and the bow-tie slot keeps constant the amount of power radiated. The structure is designed for the millimeter-wave band. The enhancement of the element performance is shown through simulation results. A fractional bandwidth of more than 100% is achieved in the 70 GHz band, and the radiated power remains almost constant throughout 30 GHz of the bandwidth. These results show a great improvement over the original radiating element. The radiating structure has the ideal characteristics for building series-fed reconfigurable arrays for wide-band applications in the millimeter-wave band.**

***Index Terms*—bow-tie slot, broadband radiating element, cavity-backed slot, millimeter-wave, stripline, traveling-wave.**

I. Introduction

The increasing number of applications in the millimeter-wave band have brought attention to antenna systems at these frequencies. For these applications, reconfigurable and high-gain antennas are typically desired. Traveling-wave antennas, especially of the leaky-wave type, are good candidates to solve the problem of the phase shifters in mm-wave antenna arrays [1]. This is due to their simple-feeding and frequency-scanning capabilities.

The so-called complementary strip-slot is a radiating element in transmission configuration introduced in [2] which overcomes the resonant nature of the traditional microstrip-fed slot. The bandwidth broadening was achieved by placing a complementary stub beneath the slot. By using this technique, the impedance bandwidth of the element was greatly increased while keeping the radiated power approximately constant [3]. As any slot printed in a single ground plane, it presents bilateral radiation.

The authors have recently modified this radiating element in order to obtain unidirectional radiation [4]. This was done by feeding the slot using a stripline instead of a microstrip. The structure was closed using SIW-like metallic posts, as in [5], leaving a cavity behind the slot. The Cavity-Backed Slot (CBS) proposed in [4] shows around 50% fractional bandwidth, and a slot-like unidirectional radiation pattern. However, the original complementary strip-slot had a wider impedance bandwidth and a more constant radiated power. This is due to the cavity behind the slot in the stripline version, which resonates at its resonance frequency, preventing the element from working properly.

In this work, a modification of the stripline radiating element is proposed to improve the stability of the radiated power along the bandwidth. Changing the shape of the slot into a bow-tie keeps the radiated power constant in a significantly wider bandwidth. In addition, the length of the bow-tie slot is shorter than the length of the rectangular slot, making the cavity shorter and the resonant frequency higher. Furthermore, the shape of the cavity is also modified to resemble a bow-tie. With this configuration, the resonance frequency of the cavity is increased even more without preventing the slot from radiating. Another novelty of this work is the use of this element in the millimeter-wave band. The analysis of the element done in [2] and [4] is still valid for higher frequencies. A disadvantage of the CBS radiating element is that, in some cases, its total thickness can be too large. As it is expected, increasing the working frequency of the element reduces its overall size, making it more compact and suitable for integration. For these reasons, the radiating element presented here is a very good candidate to build reconfigurable arrays for millimeter-wave frequencies.

II. Proposed Structure and Design

The geometry of the structure is very similar to the one in [4]. The main difference is the shape of the slot and cavity which, instead of being rectangular, are now bow-tie-shaped. The proposed geometry is shown in Fig. 1. The new shape of the slot makes its radiation more uniform in the working frequency band, while the shape of the cavity increases the resonance frequency of the resonant mode inside the cavity. This resonance determines the maximum operating frequency of the radiating element. The feeding stripline is asymmetric with a homogeneous dielectric.

The slot length, l_{slot}, has been designed to have its resonance around 70 GHz. This resonance is also dependent on the size of the cavity, which must be previously designed to allow the propagation of the slot mode, as explained in [4]. The maximum width of the slot, w_{slot}, is chosen to ensure

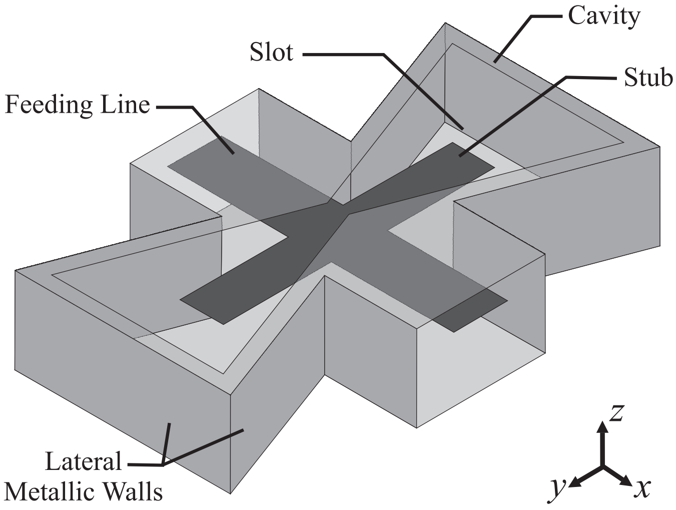

Fig. 1. Geometry of the proposed structure.

that the angle between the bow-tie is 130 degrees, which is a standard value. The shape of the cavity is the same as the slot, but its dimensions are larger enough to contain the slot. Once the slot is designed, the stub dimensions, l_{stub} and w_{stub}, must be adjusted to obtain a broad impedance bandwidth. The impedance of the feeding stripline is 50 Ω. Metallic lateral walls are used in this design but they could be implemented using metallic posts in the same way as in [4] and [5]. All the dimensions of the proposed structure are shown in Fig. 2.

III. Results

The structure from Section II has been simulated using the ANSYS HFSS commercial electromagnetic simulator. Fig. 3 shows the magnitude of the S_{11} and S_{21} parameters. As expected, a very broad impedance bandwidth is achieved. The existance of the cavity resonance is clearly seen at 103 GHz in Fig. 3, increasing the losses at that frequency. Fig. 4 shows the simulated values of the radiated power to input power ratio. The structure starts radiating significantly around 30 GHz, thus the working bandwidth of the element spans from 30 GHz up to about 100 GHz (more than 100% fractional bandwidth). Compared to the result in [4] (48%), the fractional bandwidth has been increased noticeably. It is worth noting that, from 70 GHz up to over 100 GHz, the radiated power to input power ratio is almost constant. Finally, the simulated radiation pattern is shown in Fig. 5. The results show a very stable radiation pattern along the working bandwidth.

IV. Conclusion

A bow-tie slot configuration for a previous broadband CBS radiating element for traveling-wave arrays has been proposed. The cavity is also modified to improve the impedance bandwidth of the structure. This is the first time that this element is proposed at millimeter-wave frequencies. Simulation results show a very wide impedance bandwidth and an almost flat radiated power. These characteristics make the element very

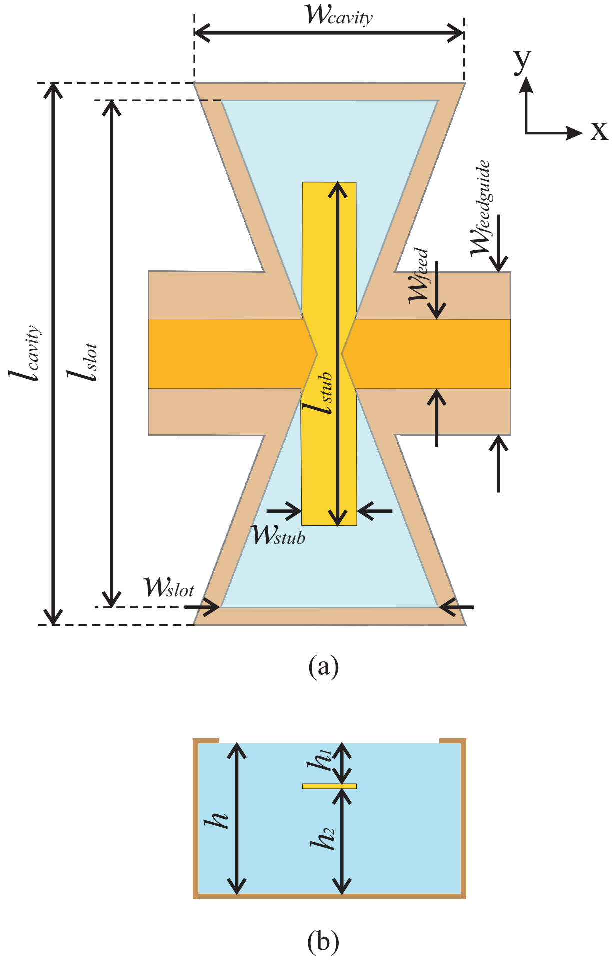

Fig. 2. Top and side views of the proposed structure with dimensions. (a) Top view (w_{feed} = 0.38 mm, $w_{feedguide}$ = 0.9 mm, w_{cavity} = 1.5 mm, l_{cavity} = 3 mm, w_{stub} = 0.3 mm, l_{stub} = 1.9 mm, w_{slot} = 1.2 mm, l_{slot} = 2.8 mm). (b) Side view (h = 0.6 mm, h_1 = 0.15 mm, h_2 = 0.45 mm).

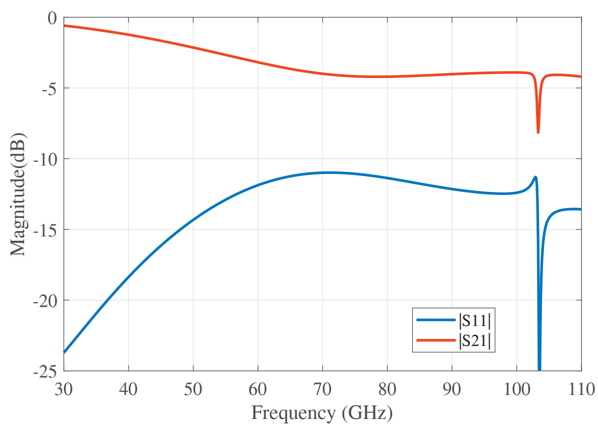

Fig. 3. Magnitude of the S-parameters of the simulated structure.

suitable to build series-fed arrays in the millimeter-wave band for applications such as new-generation communications and radars.

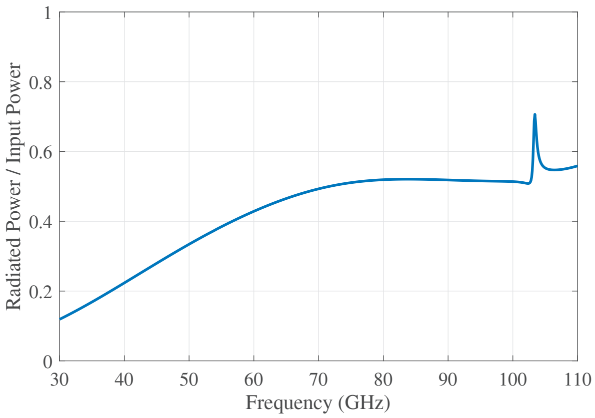

Fig. 4. Radiated power to input power ratio of the simulated structure.

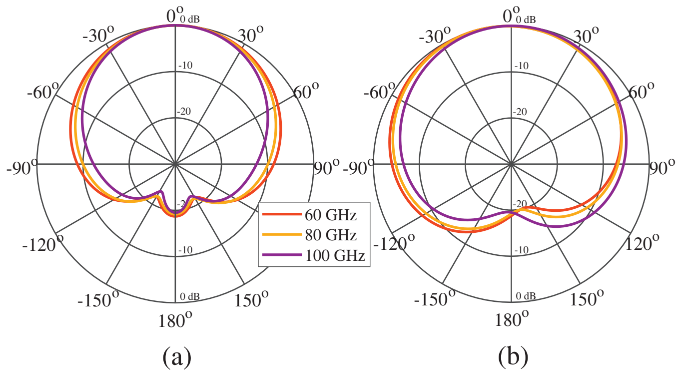

Fig. 5. Normalized-gain radiation patterns of the simulated structure. (a) YZ plane. (b) XZ plane.

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