Novel Implementation for a Broadband Cavity-Backed Slot Fed in Transmission Configuration

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***Abstract*—A novel radiating element proposed previously by the authors is alternatively implemented using enclosed microstrip configuration. The radiating element shows broad impedance bandwidth and unidirectional radiation pattern. Its transmission configuration makes it ideal for series-fed arrays. The new implementation presents significant improvements concerning easiness of fabrication, robustness and compatibility with other technologies. A prototype designed to work in the 6 GHz band has been fabricated and measured, and has shown the expected performance: a 50% of fractional impedance bandwidth and unidirectional, stable radiation patterns.**

***Index Terms*—Broadband radiating element, cavity-backed slot, series-fed antennas.**

I. INTRODUCTION

Over the last decades, slot-like antennas have demonstrated their many advantages and have been intensively employed. However, they are usually not suited for wide bandwidth applications due to their resonant nature and narrow impedance bandwidth. In [1], a radiating element for series-fed arrays was proposed which presented an ultra-wide impedance bandwidth using a slot fed by a microstrip line, where a complementary strip element was placed. This element, the so-called complementary strip-slot, exhibited bilateral radiation.

In order to extend the applications of the complementary strip-slot, the authors proposed in [2] a slot-like element based on the same principle which radiates only into one half-space. To achieve this, the structure was closed, forming a Cavity-Backed Slot (CBS), and was fed by an asymmetric stripline, also in transmission configuration. Unlike other CBS-based radiating elements found in the literature [3], [4], the proposed element showed a very broad fractional impedance bandwidth of 48%. To the authors' knowledge, this radiating element presented the widest impedance bandwidth among other unidirectional radiating narrow slots in the bibliography.

The prototype presented in [2] had several implementation issues: it required three layers of substrate, the fabrication process was somewhat sensitive and inaccurate, and the employed symmetric stripline connectors did not match the structure properly. In this contribution, a new implementation for this structure is proposed and a new prototype has been fabricated. Measurements show expected results. The new prototype also corroborates the viability of the proposed element and increases its implementation possibilities.

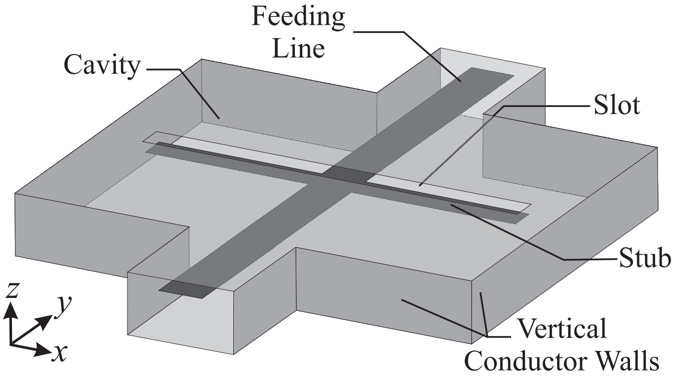


Fig. 1. Geometry of the proposed structure.

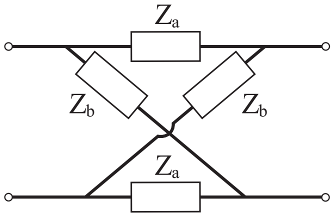


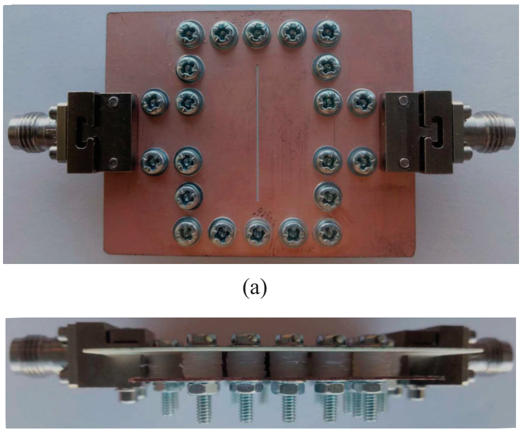
Fig. 2. Generic lattice network.

II. PROPOSED STRUCTURE

The proposed radiating element consists of a closed structure with three metallic layers excited in transmission configuration by an asymmetric stripline. The stripline feeds a slot etched on the top metallic layer. The complementary element of the slot, the strip, is placed just beneath it, in the middle layer along the stripline. Fig. 1 shows the geometry of the proposed structure.

A lattice-network circuit model was proposed in [2] as a method to achieve broad impedance bandwidth. Fig. 2 shows the topology of this network. This model separates the slot and stub impedances in the branches of the lattice network [1]. For this radiating element to achieve wide impedance matching, the slot and strip must be complementary. This happens when the impedances associated to the slot and stub, Z_a and Z_b respectively, present their poles and zeros close in frequency. This will make the structure have an approximately constant image impedance in a wide frequency band.

The complementary elements are covered by the lower



(a)

(b)

Fig. 3. Fabricated prototype. (a) Top view. (b) Side view.

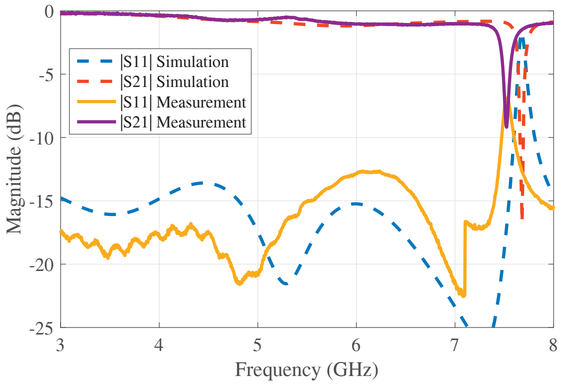


Fig. 4. Magnitude of the S-parameters of the simulated and measured structure.

metallic layer and vertical metallic walls, forming a cavity with the top metallic layer. This has two consequences: the slot element behaves as a CBS and the cavity can propagate the TE modes of a rectangular waveguide in the transverse direction (along the x axis in Fig. 1). By changing the dimensions of the cavity, it is possible to avoid the propagation of the TE modes within a given bandwidth. Although the CBS presents several differences compared to traditional slots [5] (cut-off frequency and propagation constant of the radiating mode, impedance level...), satisfactory designs are achievable by carefully dimensioning the cavity and readjusting its poles and zeros to achieve complementarity.

III. IMPLEMENTATION AND DESIGN

The implementation proposed in [2] consisted of three different, very thin substrates. One of them was used for the slot and upper ground plane, another one for the stripline and stub and the last one for the lower ground plane. The metallic lateral walls were made with steel screws and the three layers were suspended using nylon washers. Symmetric stripline connectors were used.

An alternative, simpler implementation is proposed in this contribution. Its structure is formed by three items: the first one, a microstrip substrate with both complementary elements printed, one on each side; the second one, a copper sheet which is placed beneath the microstrip line, leaving a gap of air between them; the last one, the metallic walls which are made by steel screws, connecting both ground planes. To keep a fixed distance between the substrate and the copper sheet, nylon washers have been placed around the screws. This way, microstrip connectors could be used and only one layer of substrate is needed, unlike the prototype in [2].

Using the design considerations described in [2], a design was carried out. The substrate employed was Rogers RO4350B with dielectric constant, ε_r, of 3.66 and thickness 0.51 mm. The height of the substrate was chosen small enough so the stripline feeds the slot properly but big enough so the slot mode is not altered by the strip. A 50 Ω microstrip line of 1.1 mm of width was chosen as the feeding line. The width of the cavity was set to 22.4 mm and, thus, the cut-off frequency of the TE_{10} mode is approximately 6.7 GHz. The distance from the substrate to the lower ground plane was fixed to 3.2 mm and the width of the slot to 0.3 mm in order for the CBS mode to be propagated from the frequency of 3.4 GHz upwards. The width of the strip was also set to 0.3 mm to achieve an impedance level of 50 Ω. After, the lengths of the complementary elements were designed so that the first pole and zero are around the frequency of 5.2 GHz, resulting in a length for the slot of 22 mm and 18.6 mm for the strip. The length of the cavity is larger than the length of the slot, 32 mm. Finally, the screws had a diameter of 2 mm and were placed with a separation of 5.6 mm between them.

The result of the fabrication process led to a simpler and more robust prototype, as shown in Fig. 3. Furthermore, a TRL calibration kit was designed and fabricated in order to obtain measurements with coincident reference planes in the middle of the structure.

IV. RESULTS

The built prototype was measured using the TRL calibration kit. Fig. 4 shows the magnitude of its S-parameters compared to simulation results obtained using the software tool ANSYS HFSS. Good agreement between them has been found. The working frequencies of the element are limited by its low radiation up to 4 GHz and by the resonance of the TE_{101} mode of the cavity at 7.5 GHz. The fractional impedance bandwidth of this prototype is 50%. The reflection coefficient is lower than -12 dB in the working band.

To provide some insight about how the element works, Fig. 5 shows the imaginary part of the impedances of the lattice network of the element extracted from simulation and measurements. As previously mentioned, it is possible to see that the pole and the zero are placed around the same frequency, which explains the broad impedance bandwidth.

Regarding its radiation properties, only simulation results are available at this moment. It is expected that the radiation

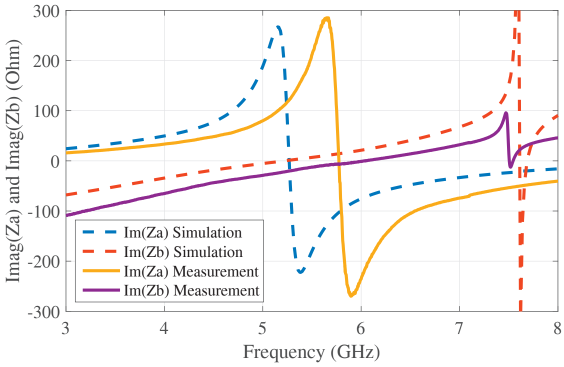


Fig. 5. Simulation and measurement of the imaginary parts of the impedances of the lattice network of the radiating element.

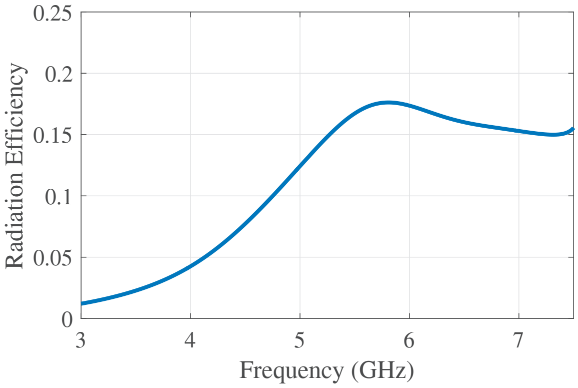
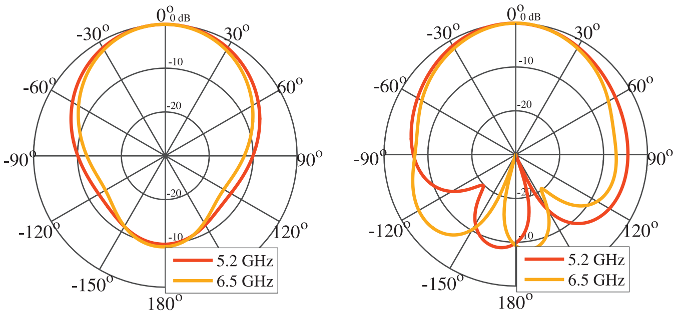


Fig. 6. Simulated radiation efficiency of the proposed element.

characteristics measurements will be available at the time of the event. Fig. 6 shows the radiation efficiency. This radiation efficiency has been calculated as the radiated-accepted power ratio, as in the 'leakage factor'. As expected for radiating elements fed in transmission configuration, most power is carried to the second port and, in this case, only around 15% is radiated. This is an interesting feature to build series-fed arrays. Fig. 7 shows radiation patterns of the simulated prototype at 5.2 GHz and 6.5 GHz. As expected, broadside radiation into only one half-space is obtained, and radiation patterns are similar at both frequencies. The obtained polarization is linear, with a very high cross-polarization discrimination.

V. CONCLUSION

A new implementation for a broadband CBS radiating element fed in transmission configuration has been proposed. The implementation presents a much simpler fabrication process and a robust profile. Measurements of the new prototype satisfy the expectations in terms of impedance bandwidth and radiation properties set by the previous prototype and confirms the excellent features of this radiating element. This alternative way of fabrication also provides the structure with new integration possibilities for upcoming applications.



(a)

(b)

Fig. 7. Simulated co-polar radiation patterns of the element at 5.2 and 6.5 GHz. (a) H-plane. (b) E-plane.

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