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Additional Information

A Novel Circularly-Polarized T-shaped Slot Array Antenna in Ka-band

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Abstract—A T-shaped slot-array antenna fed through a Groove Gap Waveguide (GGW) is presented in this paper. The array antenna operates at 30 GHz. The way the slots are excited, along with the T-shape on its lid allows a compact single-layer architecture. A uniform linear array of 12 elements is designed to demonstrate the viability of this concept for high-efficient single-layer slot-array antennas. Preliminary results show a frequency bandwidth of 1 GHz with input reflection coefficient better than -12 dB. In addition, being a full-metal antenna, the expected efficiency is high. It is worth stressing the good polarization purity achieved, being below 1.5 dB within the band of interest.

Index Terms—Gap waveguide technology, Ka-Band, slotted-waveguide antenna, Circular polarization, T-shaped slot

I. INTRODUCTION

Due to their electrical and physical advantages such as high gain, efficiency, and low-profile, slotted waveguide array antennas are extensively used for many mm-wave communication systems. The dimensions of the slots in the waveguide walls can be controlled to realize the desired pattern shape. Longitudinal shunt slot arrays are also attractive due to their very low cross-polarization levels. Over the recent decades, the conventional waveguide-fed resonant shunt slot array antennas have been designed with well-established design equations that consider both internal and external coupling effects [1].

Initially, longitudinal slot arrays were the most frequently used given their polarization purity, but other slot geometries have been sometimes proposed such as inclined slots or transverse slots [2], [3]. All of them share a linearly polarized radiation pattern. Typically, circular polarization in arrays has been achieved using dielectrics [4] [5] or printed polarizers [6]. There exist few examples of full-metal circularly polarized slot array antennas. The motivation to find more versatile antennas, not only linearly-polarized (LP) arrays but with dual or circularly-polarized (CP) performance has encouraged new structures, taking advantage of the previously mentioned benefits of slotted-waveguides.

The great advantage of the antenna proposed here is its simplicity, since it is built following the same basic principles as for conventional shunt slot arrays, with just a small modification on its lid. In addition, the antenna is designed using Gap Waveguide (GW) technology to overcome the drawbacks that come from conventional metallic rectangular waveguides [7]. GW technology avoids the need of contact between all the metallic parts of the structure. Even without contact, the field is confined inside the waveguide and leakage is avoided. This

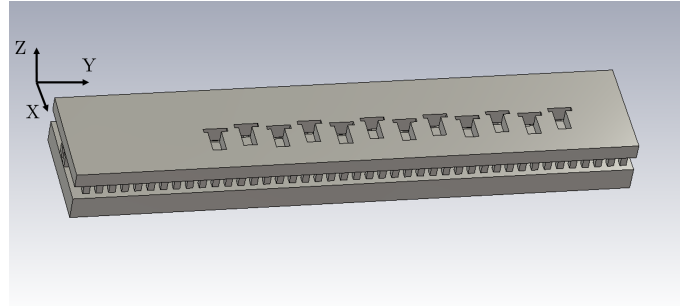


Fig. 1: Perspective view of the CP Linear Slot Array

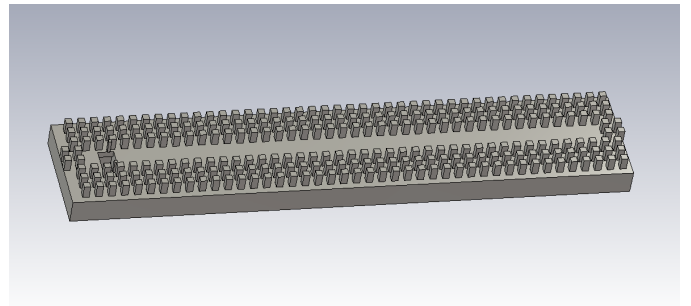


Fig. 2: Perspective view of the antenna without the lid.

property is a key aspect in the millimeter-wave band, where waveguide assembly is critical.

The short-term motivation of this work is to explore the possibility of extending this design into a single-layer two-dimensional array that would be very attractive for satellite communications on the move in Ka-band or 5G applications. In this paper, it is described in detail the 12-element linear slotted waveguide array, to later present its preliminary results in section III, ending section IV with the conclusions.

II. LINEAR SLOTTED WAVEGUIDE ARRAY ANTENNA

Basically, the linear array consists of twelve shunt slots, which have been placed side-by-side. Linear slots are transformed into T-shaped slots on the lid and so the array is able to provide circular polarization with an axial ratio below 1.5 dB in a frequency bandwidth larger than 1 GHz.

The antenna is made up of three fundamental parts that are going to be detailed next. Each of the parts plays a fundamen-

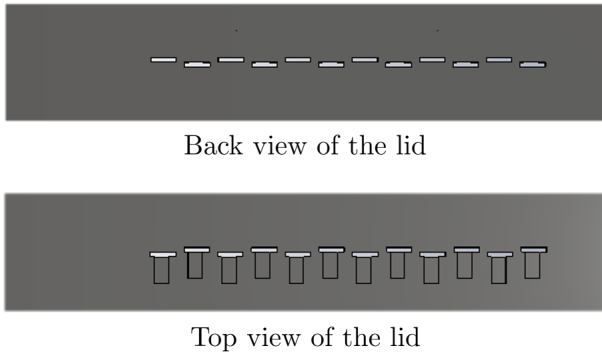


Fig. 3: Back view and top view of the lid.

tal role within the entire structure. First of all, the use of Gap Waveguide (GW) technology is not trivial. Thanks to GW, it is not necessary that the lower metallic piece has contact with the top cover. In fact, there is an air gap of 0.556 mm between both metal parts. Secondly, the feeding is done from the bottom for practical reasons (ease of measurement, for example), but also for performance reasons. A lateral feeding would degrade the aforementioned property since that lateral metallic piece would force the contact between the upper and lower layer.

Finally, the most important particularity is on the lid, which, with a simple structure, is able to transform the LP into CP. The following subsections delve into these aspects.

A. The T-shaped Slot

The total thickness of the radiation layer is 3.5 mm. It is important to underline, as shown in Fig. 3, that the lid is different on both sides. On the lower side, that is, the side that is internal together with the GGW, is the one with longitudinal slots with a small offset from the center of the waveguide. The height of these primary slots is 3.5 mm as they cross entirely the radiation layer.

On the other hand, the outer layer has the T-shaped slots. That is, for each longitudinal slot another slot is drilled perpendicular to it. The depth of this parasitic slot is 3 mm, so it does not reach the bottom of the lid. In addition, this slot is slightly offset from the center of the primary slot to be excited. All the relevant dimensions are indicated in Fig. 4. By adjusting the offset of the primary slot T and the length of the parasitic slot, a good CP purity is achieved.

B. Groove Gap Waveguide

One type of GW is the GGW, which consists in creating a groove in the desired path of wave propagation. This groove is surrounded by a periodic alignment of nails acting as the walls of waveguide to prevent from leakage on laterals. The basic dimensions of these nails are: 3 mm high and 1.5 mm wide, with a periodicity of 2.5 mm between them. For practical purposes, it can be considered that the behavior of the GGW is

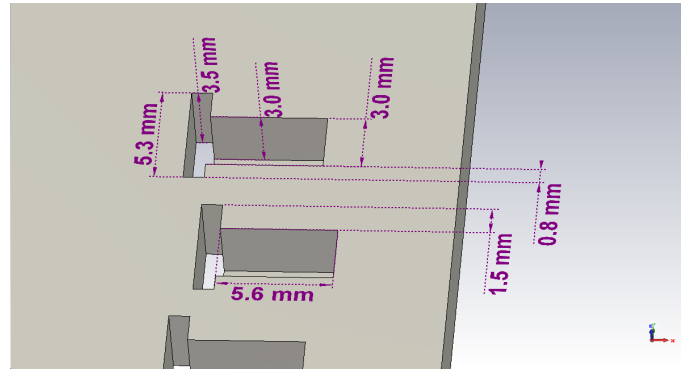


Fig. 4: Detail and dimensions of the T-shaped slot.

very similar to that of a rectangular waveguide. The advantage of the first over the second is its ease of assembly, being its losses very similar [8].

C. Input Port

The input port is placed at the end of the GGW to generate the resonant mode. To achieve the best matching possible, the distance from the transition to the short-circuit is considered. In addition, one capacitive step is used to adjust the impedance between the input port, and the GGW.

III. SIMULATED RESULTS

The slot-array antenna has been implemented and simulated with the full-wave simulator tool CST.

The reflection coefficient is shown, first, in Fig. 5. The S_{11} -parameter in the central part of the band (29.7 to 30.4 GHz) is below of -20 dB and goes up to -12 dB on both edges of the band. Nevertheless, those values are also acceptable since they are below -10 dB.

As Fig. 2 shows, the Groove Gap Waveguide is fed from the bottom. This will facilitate a future antenna measurement. Otherwise, the flange WR-28 would be placed on one side of the GGW and this would entail adding a metal piece at one end of the antenna, thereby spoiling the GGW contactless benefit and perturbing the radiation performance.

Figs. 6 and 7 show the radiation patterns on the main planes of the antenna at the lower, central and upper frequencies of the pass band (29.5, 30 and 30.5 GHz). The radiation pattern illustrates the uniform illumination of the elements, since the side lobe level (SLL) is close to -13.2 dB. Moreover, the crosspolar component is low enough, below -20 dB within the bandwidth.

The good crosspolar level can be also observed in the axial ratio showed in Fig. 8. In this figure, an axial ratio below 1.5 dB is observed within the operating frequency band (see shadowed area in the figure). Besides, the 3dB axial ratio Bandwidth is from 29 to 31 GHz. The 12-elements linear array provides a directivity greater than 16 dBi in the entire band of interest. Table I highlights some important simulated results of the antenna performance.

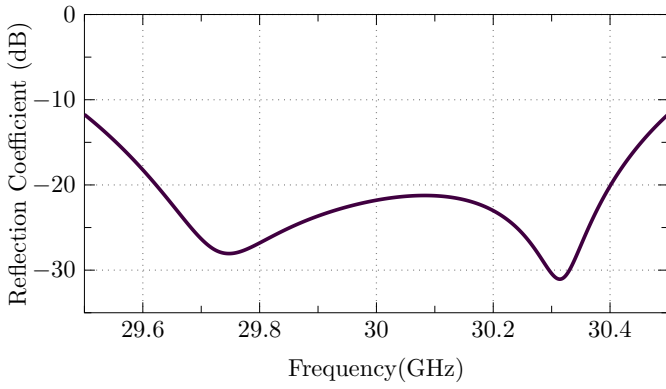


Fig. 5: Simulated reflection coefficient of the linear array.

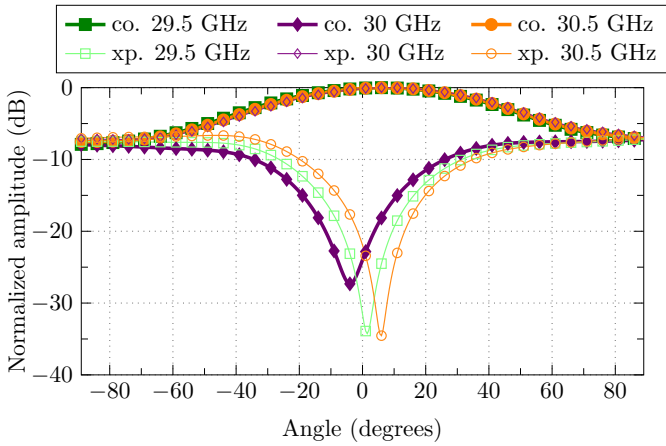


Fig. 6: Simulated radiation pattern ($\phi = 0^\circ$)

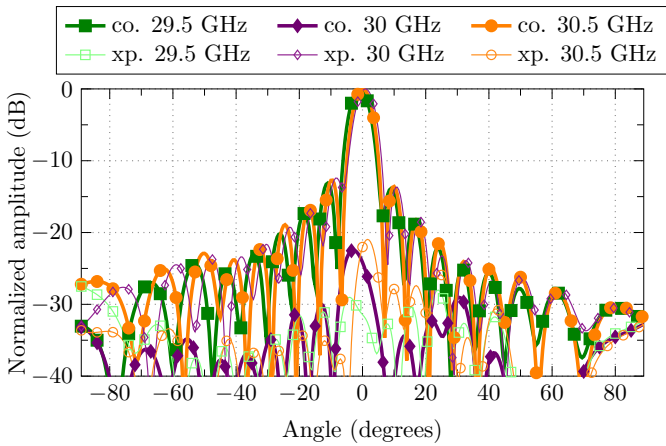


Fig. 7: Simulated radiation pattern ($\phi = 90^\circ$)

TABLE I: Simulated antenna parameters of CP array.

Frequency (GHz)	29.5	29.75	30	30.25	30.5
Directivity (dBi)	16.64	16.90	16.90	16.78	16.29
Axial Ratio (dB)	1.10	0.64	0.46	0.86	1.42

IV. CONCLUSION

A new T-shaped slot array antenna in gap waveguide technology is presented. It is a promising structure since with

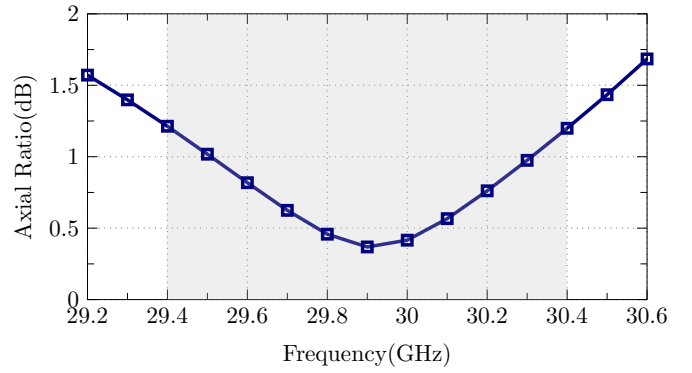


Fig. 8: Simulated axial ratio performance.

a small variation with respect to the well-known design of a SWA, a truly attractive circular polarization performance is achieved. In the Ka band, there are applications such as 5G technology or satellite communications on the move, eager for solutions such as compact antennas with circular polarization performance, which can be affordable and have a low profile. The challenge of extending the proposed design to a 2-dimensional and scalable array to obtain a higher gain and lower side lobe levels.

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