Comparison of a slotted SIW antenna covered with metasurface vs. a traditional array

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***Abstract*— In this article we compare two solutions to improve the radiation pattern of a slotted Substrate Integrated Waveguide (SIW) antenna: use of an E-plane array and covering it with a metasurface (MTS). To this aim, we compare the changes in performance, radiation pattern and aperture efficiency. We will see the advantages that the metasurface has over the typical array.**

Keywords—Substrate Integrated Waveguide, Metasurface, Array, Slotted Antenna.

I. INTRODUCTION

As more complex and compact devices are developed [1], the need to design more compact systems arises. In this context, antenna miniaturization [2] or the use of metasurfaces (MTS) to increase the aperture efficiency [3] are solutions that can be found in the literature.

In this case, we propose the use of a metasurface [4] [5] with which we will improve the radiation performance of a slotted Substrate Integrated Waveguide (SIW) antenna. The metasurface follows a layer-by-layer configuration which consists of three layers: 2 of them are composed by paired dipoles and the one in between the dipoles is formed by long wires. This MTS has a bandpass at the working frequency, which in this case will be 24 GHz. This can be a good solution for low profile antennas like the one we are going to use, since it is printed on the same type of substrate as the SIW, on a commercial Rogers 5880 substrate with a permittivity of 2.2 and loss tangent 0.0009.

In this work, we will use the metasurface on an slotted SIW antenna, where we will implement a Chebyshev distribution, which will allow us to control the side lobe level in its H-plane. However, in the E-plane a broad pattern is obtained, which is dominated by the slots. We will compare two solutions to control the radiation pattern in the antenna E-plane. The first one uses and array of two antennas, whereas the other one is based on the above mentioned MTS on top of the antenna. This MTS allows increasing the effective aperture and therefore controlling the antenna pattern.

In the first section, we will show the design we have followed for both antennas. In the second section, the main comparison results will be shown. Finally, we will present the conclusions.

II. ANTENNA DESIGN

For the design of both antennas, we first had to design a guide in standard SIW, for this we fulfilled the equations given in [6][7] so we obtain these values in our main variables.

TABLE I

Description	Values (mm)
Width	6.19
Diameter Vias	0.5
Distance between Vias	0.7

A. Array of slotted SIW antennas

Fig. 1 shows the proposed 1x2 array of slotted SIW antennas. Each of the array elements it is a standard slotted SIW antenna, designed to achieve a Chebyshev distribution with -20 dB sidelobe level. The separation between the centers of the SIWs will be varied from 8 mm to 12.5 mm, 0.65 λ to λ. Distances shorter than 0.65 λ are not possible due to the physical width of the SIWs. Even though in a real array a distribution network would be required, for this study SIW is independently fed by a SIW port.

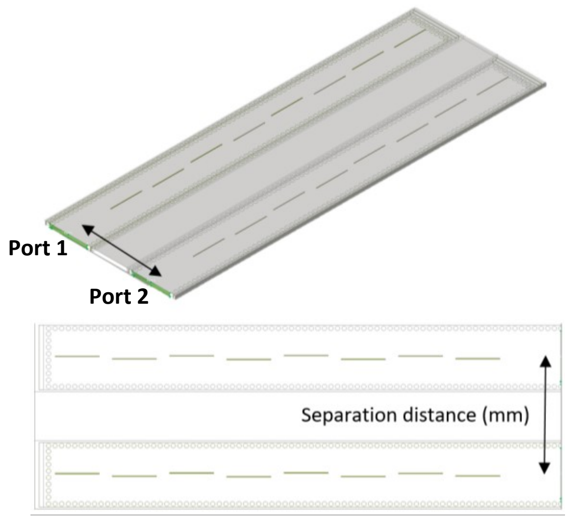

Figure 1. Schematic of the 1x2 slotted SIW array.

B. Antenna covered with metasurface

The next design corresponds to the SIW antenna covered by the previously mentioned metasurface. In this case, just a slotted SIW is used to illuminate the MTS. This SIW antenna has been designed following the same steps as in [8]. An schematic of the resulting design is shown in Fig. 2.

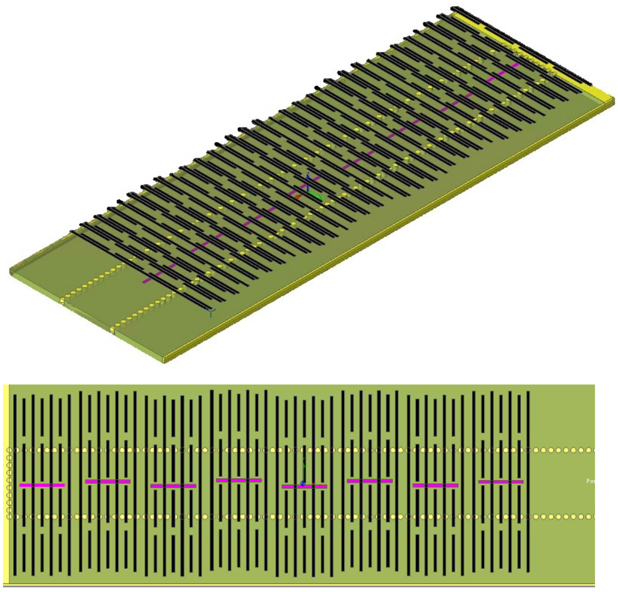

Figure 2. MTS covered SIW antenna. The metal and the substrate have been removed to improve the visibility of the slots and MTS

As can be seen, Fig. 2, the dipole layer is placed perpendicular to the slots so that the electric field excites them correctly. In addition, each MTS unit cell consists of 4 x 3 dipole pairs and 4 wires. Their position follows the of the slots, which are determined by the intended Chebyshev distribution.

In the next section, we will show the simulation results of these antennas.

III. Results

Fig. 3 shows the radiation pattern on the SIW array for several separation distances. It is well known, that as the distance increases, our array factor changes, increasing the visible margin, and consequently, grating lobes appeared which cause a decrease in gain. For this reason, the shortest separation distance shows the best performance, with maximum gain, 16.6 dB, and sidelobe level below 17 dB.

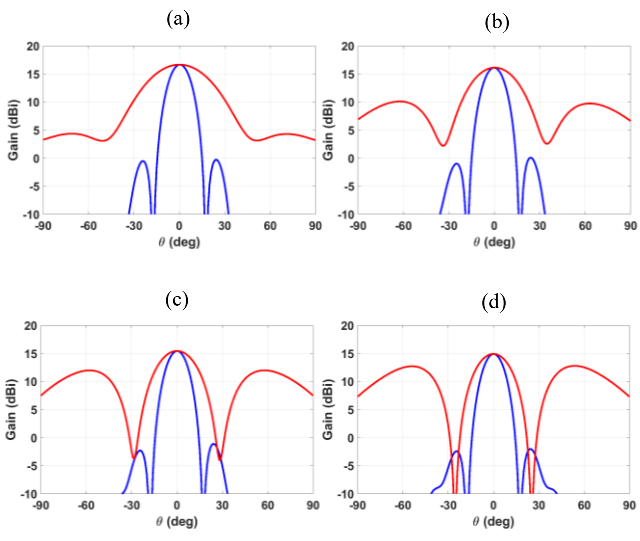

Figure 3. Radiation pattern of the 2x1 SIW array for different separation distances. E-plane (red-line) and H-plane (blue-line). (a) 8 mm; (b) 9.5 mm; (c) 11 mm; (d) 12.5 mm

Another important parameter when studying this type of arrays antennas is the coupling coefficient between the SIW waveguides. We see in fig. 4 that when the distance increases, coupling is lower, as expected. In all case the coupling level is lower than 13 dB.

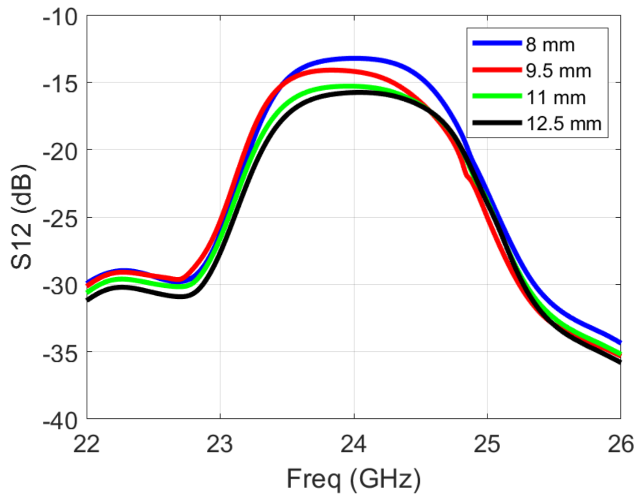

Figure 4. Coupling coefficient of the antenna Array for different separation distances.

Having shown the most relevant results of the array, we will now compare the two solutions. An important result is their frequency response and the bandwidth of the antennas. Fig. 5, shows the antenna return loss of the metasurface covered SIW and of the SIW array with 8 mm distance. This distance was selected, since it provided the same gain that the MTS covered SIW.

We can see no significant difference between the response of both antenna. In terms of bandwidth, we have the same bandwidth in the two antennas, 1 GHz, which corresponds to about 4.1 %.

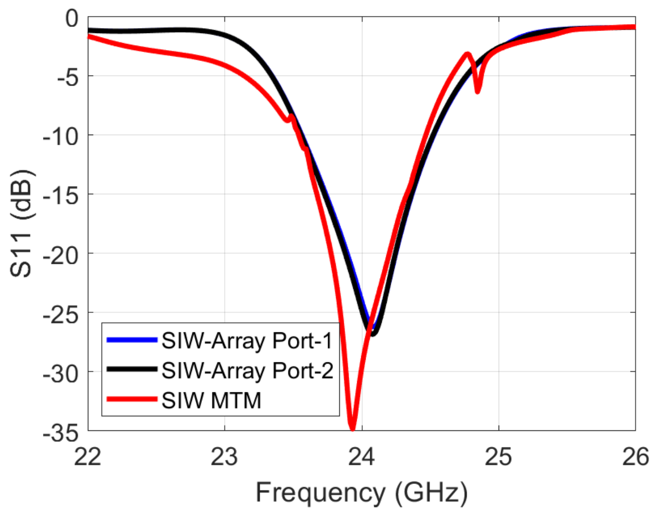

Figure 5. Reflection coefficient of the SIW antenna array compared with the antenna covered with the MTS.

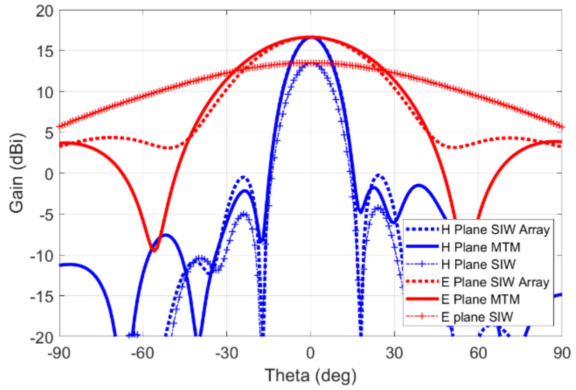

Figure 6. Radiation pattern, comparison between Antenna Array vs Antenna covered with the MTS. (Realized Gain)

Fig. 6 shows the radiation pattern of antennas. It can be seen that the antenna covered with the metasurface achieves similar performance as that featured by the antenna array. The radiation pattern of the SIW without array is showed for better comparison.The SLL in the H-Plane gives better results when we use the metasurface; that is because the Chebyshev distribution is better fulfilled. Regarding the E-Plane, similar response is obtained, although the MTS requires a single feeding point which simplifies its design.

IV. Conclusions

The comparison between the performance of two solutions to control the radiation pattern of slotted SIW antennas has been presented in this paper. The standard solution, based on an array in the E-plane can be limited by the appearance of grating lobes and by the mutual coupling for large and short distances between antennas. In the second solution a MTS is placed on top of the slotted SIW antenna to increase the radiation aperture and control the radiation pattern. With this solution similar performance to that achieved with the antenna array can be obtained, without requiring a distribution network.

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