H-band Multilayer Waveguide Using Glide Symmetric EBG

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***Abstract*—This work presents a fully metallic air-filled multilayer waveguide (MLW), that utilizes a glide symmetric unit cell as electromagnetic band-gap for improving manufacture tolerance. The proposed MLW is designed for the H-band, $220-330$ GHz, obtaining an insertion losses below 0.4 dB. Additionally, the electromagnetic properties of the used unit cell, in particular its stopband attenuation, are investigated with the multimodal transfer matrix method, to better understand its physics.**

***Index Terms*—gap waveguides, glide symmetry, H-band, multilayer waveguide.**

I. Introduction

The H-band ($220-330$ GHz) is reserved by the Federal Communications Commission (FCC) and the Body of European Regulators for Electronic Communications (BEREC) for applications such as high-resolution imaging, spectroscopy, and advanced communication systems. These applications leverage the unique properties of the H-band to provide high-resolution, non-intrusive, and highly sensitive measurements, making it a powerful tool in various scientific and industrial fields [1].

Due to the transition to higher frequencies, the dimensions of the elements are significantly reduced. This reduction necessitates a highly demanding manufacturing process in terms of accuracy, which in turn leads to higher manufacturing costs. Traditional printed circuit board (PCB) dielectric material exhibited high loss tangent factor at these frequencies [2]. Thus, air-filled waveguide structures are preferred; however, the dimension of such waveguide sturcture is also demanding in term of machining accuracy. To ease the tolerance of manufacturing, perfect magnetic conductor (PMC) are proposed to suppress unwanted leakage caused by manufacture errors. The PMC is usually implemented by a periodic structure, i.e. using gap waveguides [3]; however, this concept is hard to scale up to the H-band due to challenging of manufacture accuracy at sub-millimeter scale.

In this work, we present a multilayer waveguide, designed for H-band. In most literature, gap waveguides are implemented with two metallic plates, as e.g. in [4] and [5]. Here, instead, we make use of glide symmetric unit cells stacking several metallic layers. A glide symmetric unit cell is obtained after a translation by half a period and a mirroring of the initial one. Several previous works demonstrated that glide-symmetric structures possess a wide stopband (see e.g. [6]). The unit cell designed here is inspired by [7], that works at lower frequencies.

Moreover, the multi-gap structure unit cell stopband behavior is here studied in the H-band by means of the multimodal transfer matrix method (MMTMM) [8], [9]. With the MMTMM, we are able to obtain the complex propagation constant of modes in the analyzed periodic structure. The real propagation constants of modes are compared with the commercial CST ES software, but, to the best of our knowledge, the analysis of the attenuation in the stopband has not been published yet for a multi-gap structure.

II. Multilayer Unit Cell Analisis

In this section the analysis of a unit cell built from several metallic layers is reported. The unit cell is shown in Fig. 1(a). The structure is composed of square holes that are mirrored and shifted by half a period, constructing a glide symmetric structure. The dimensions of the unit cell are reported in Table I. A top-down and side view with dimensions can be seen in Fig. 1(b) and (c).

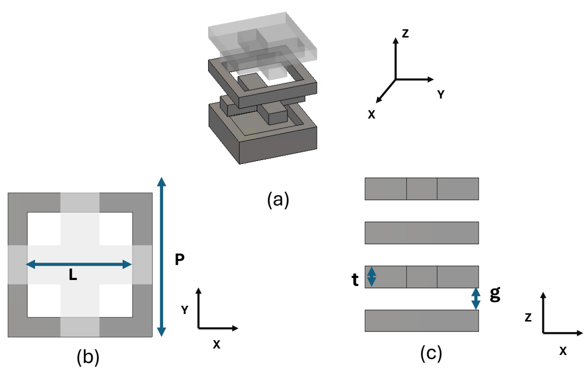


Fig. 1: (a) 3D Unit cell view. (b) Unit cell top-down view. (c) Unit cell side view.

In Fig. 2, the comparison between the real part of the dispersion diagram, obtained with CST ES and the MMTMM is presented. The stopband for this structure is between 184 and 398 GHz, covering the entire H-band. Moreover, an excellent agreement is obtained between MMTMM and CST ES.

TABLE I: Geometrical dimensions

Unit cell		
Parameter	Dimension (μm)	Description
L	480	Square hole width
P	659	Unit cell period
t	200	plate thickness
g	10	Gap between layers
Waveguide		
W1	750	Plate width
W2	860	Waveguide port width
H	432	Port height

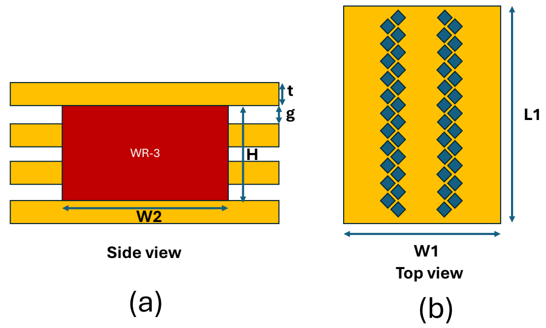


Fig. 4: MLW design. (a) Side view; (b) Top-down view.

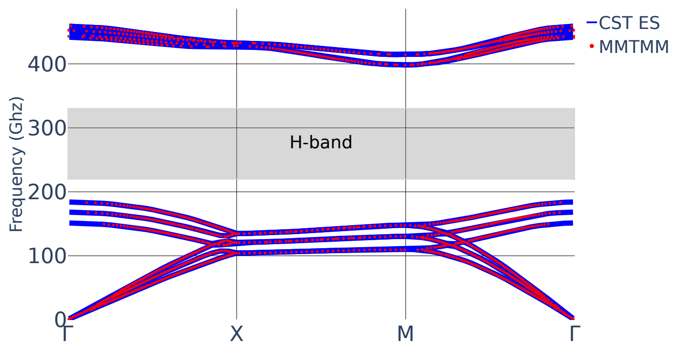


Fig. 2: Dispersion Diagram. The results of the CST ES (blue line) are compared with the MMTMM results (red dotted)

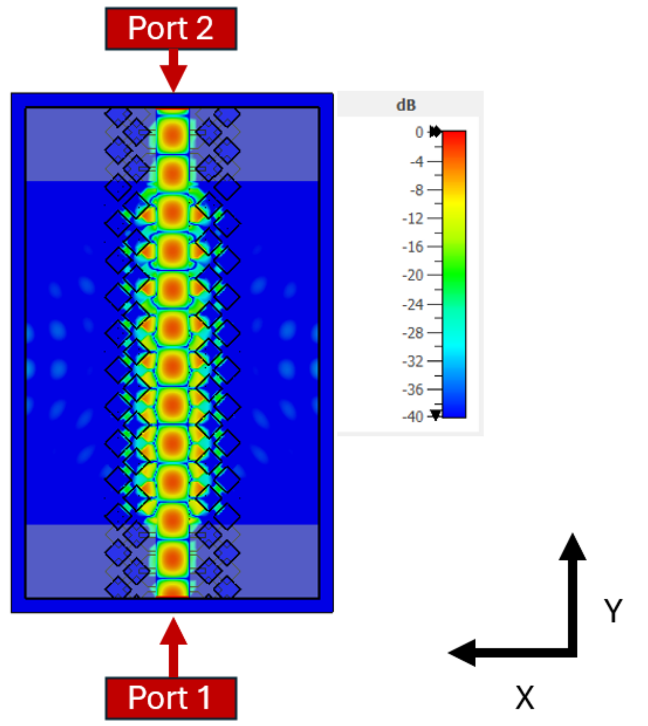


Fig. 5: E-field distribution at 230 GHz in the middle of a gap between layers

In Fig. 3, the minimum attenuation for path $\overline{\Gamma X}$ is shown. The attenuation in the $220-330$ GHz band is above 0.5 and, in some cases, exceeds 1. Such attenuation is sufficient to confine the wave in the groove a demonstrated in [10].

Considering the wide stopband and high attenuation in the band of interest, it is possible to use this unit cell as an EBG to build a waveguide for this band, as detailed in the next section.

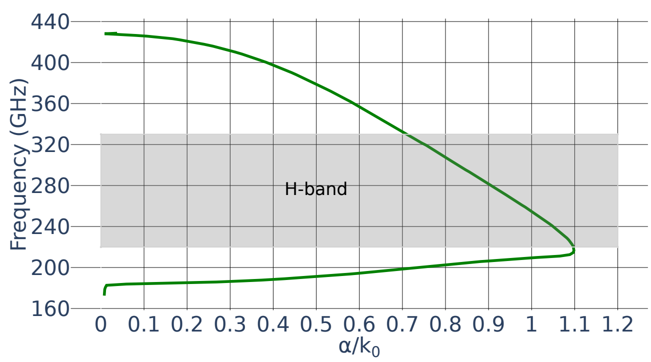


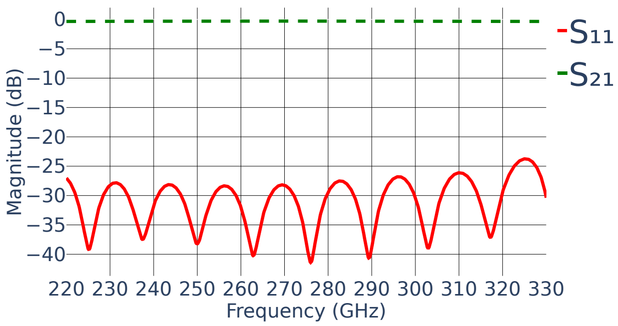
Fig. 3: Minimum attenuation in the $\overline{\Gamma X}$ path.

III. H-band Gap Waveguide

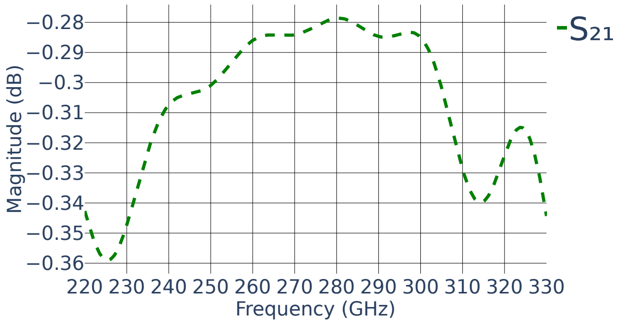
The designed gap waveguide is illustrated in Fig. 4, with dimensions listed in Table I. The unit cell is oriented in a way to maximize the attenuation, as proposed in [10].

The simulations performed with the CST time domain solver with the metallic parts modeled as a lossy gold material. In Fig. 5 the E-field distribution at 230 GHz is reported. It can be notice that the E-field is confined in the groove. In order to excite a TE10 mode a rectangular waveguide is implemented as an input. This rectangular waveguide is done with a metallic block that can be notice in Fig. 5 close to the ports.

In Fig. 6(a), the amplitudes of the S-parameters at the waveguide ports are presented. The $|S_{11}|$ is below -20 dB for the entire band. The $|S_{21}|$ is presented in Fig. 6(b): it is above -0.4 dB throught the whole band indicating that the wave is well-confined within the groove. Confirming previous results, the electric field is confined in the gap waveguide, indicating the EBG is well-designed.



(a)



(b)

Fig. 6: (a) Waveguide S-parameters in the H-band; (b) Enlargement of the S_{21}

IV. Conclusion and Perspectives

In this paper a glide symmetric unit cells, stacking several metallic layers, has been designed and used as EBG to realize a gap waveguide, working in the whole H-band. It suitably confines the wave in the groove, preventing additional losses due to leakage in the entire band. Moreover, the MMTMM is applied to the unit cell analysis, evaluating the stopband attenuation, high throughout the entire H-band.

In the future work, we aim to further analyze the performance of the unit cell with the MMTMM, including other sections of the dispersion diagram. Furthermore, we plan to utilize the MLW technology for radar design.

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