Hard waveguides based on gap waveguide concept

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Abstract

The use of periodic elements loading rectangular waveguides to miniaturize them allowing the propagation of new (backward) modes has been proposed several years ago. However all the proposed solutions have a strong limitation in terms of bandwidth and impedance matching. We propose for the first time a wide band miniaturized waveguide based on the use of artificial surfaces and the gap waveguide philosophy.

1. Introduction

The big amount of work on the last decade about periodic structures, artificial surfaces and metamaterials has produced many results with revolutionary approaches in classical designs. One of the promising ideas was the possibility of using Artificial Magnetic Conductors (AMC) to emulate Perfect Magnetic Conductor (PMC) boundary condition in the vertical walls of ordinary rectangular waveguides. In this way, the propagation of a mode fulfilling boundary conditions will be possible at a frequency much lower than the ordinary cutoff which is given by the waveguide width and this lower frequency will be defined by the AMC surface. Different authors have tried to use this idea previously with relative success [1]-[5] as in all the examples in the literature, the solutions have severe problems with the bandwidth of the mode because the AMC solution was very narrow band.

Recently, a new type of technology is being developed based on related concepts. By playing with AMC and PEC conditions, the propagation of parallel plate modes is controlled and stopped in a frequency range where also two opposite small PEC boundaries are allowed to permit propagation. This is known as *gap* waveguide and both the *ridge* and the *groove* versions of it have been carefully studied [6, 7, 8] in all cases implementing the AMC condition with a bed of nails. From those studies we know that the geometries allowing a gap to the metal plate give as result large bandwidths for the PMC condition. Inspired in this idea, this work proposes the initial study on how to replace two walls of a rectangular waveguide by an AMC separated a gap g from the metal. The idea is described in Figure 1 where also the general idea when dealing with miniaturizing waveguides is shown. The type of AMC selected for these initial studies is the mushroom-type surface, as it is flat and fits well with this application.

2. Desing of the AMC surface

The first step in designing the structure is the selection of the mushroom-type periodic surface to provide the AMC condition. The structure must be analyzed with an upper metal plate as it was studied for gap waveguide designs in [9]. In this initial study we look for an structure which provides a quite wide band. According to [9] the bandwidth was mainly dependent on the thickness and permittivity of the

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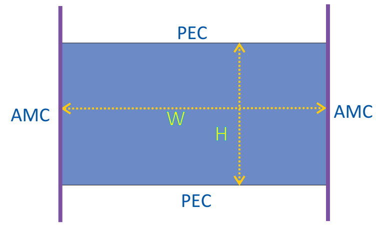
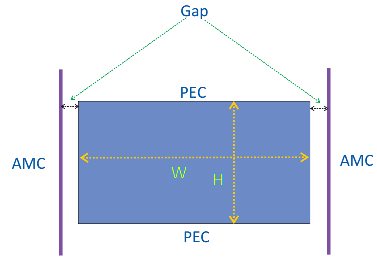


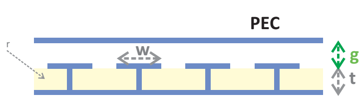
(a) Original concept



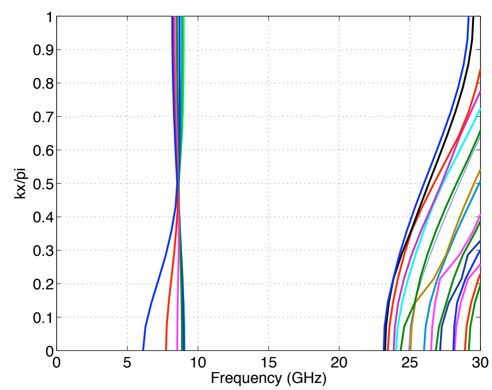
(b) Proposed modification

Fig. 1: Hard waveguide designs

substrate where the mushrooms are printed. A low permittivity with a relatively thick substrate gives the largest bandwidth. However, this results in considerably big mushrooms and limits the aperture size. Consequently we propose a compromise by using a material with thickness t=1mm and with permittivity ϵ_r=4.4. We select as frequency band the one around 10GHz. The dispersion diagram will depend as well on the "gap" (the distance to the upper plate) as discussed as well in [9] and we have selected 0.5mm to this aim. Figure 2 shows the dispersion diagram for an example in which we have selected as patch size w= 2.25mm, period p=2.5mm and as radius of the via r=0.25mm. With such values, the stop band goes from approximately 9GHz to 24GHz for the considered gap of g=0.5mm as shown in Figure 2.



(a) Mushroom-EBG

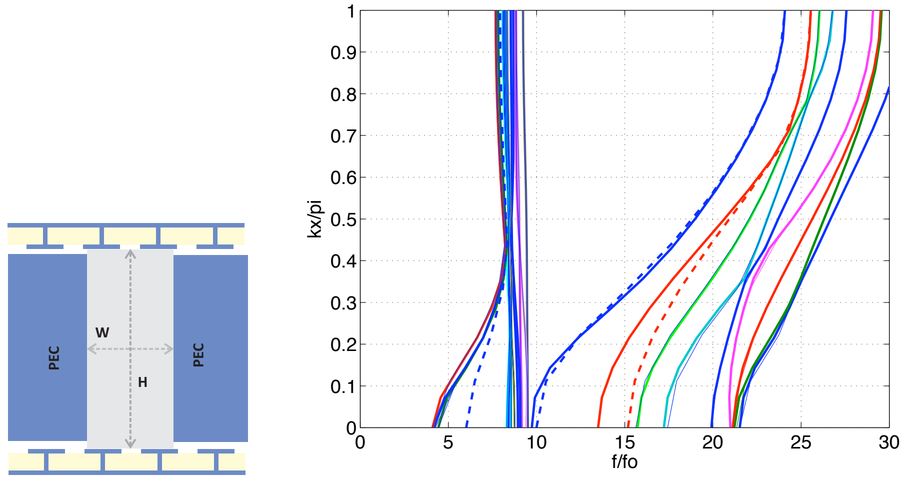


(b) Dispersion Diagram

Fig. 2: Stop band defined by the mushroom-type EBG with a gap and an upper plate

3. Considerations of design and field distribution

The aperture of the proposed waveguide is W by H as shown in Figure 3 being both W and H $0.5\lambda_0$ within the operation band. However, when some dielectric is added to the aperture we need to recompute the modes to see the cutoff frequency of the dominant one. We propose initially a waveguide with dimensions are 5mm by 5mm plus the gap and plus the two dielectric layers. Considering all these factors we have calculated the cutoff frequency of the dominant mode for such aperture (with PEC in the four walls) by running a simulation and the result gives 15GHz. This will be the upper limit for the band of the created mode. The dispersion diagram of the structure has been computed and is presented in Fig 3. We clearly see how all the parallel plate modes go to cutoff at around 9.6 GHz, when a new mode starts to propagate. This frequency is determined by the mushroom-EBG structure as shown in Fig 2. The momonode band covers from approximately that frequency to almost 13.5GHz. In the same Figure the dashed lines mean the dispersion diagram for the same aperture but with height H=3mm and for this case the upper limit of this monomode band is above 15GHz.



(a) Description (b) Dispersion diagram

Fig. 3: Waveguide designed with the double mushroom-EBG surfaces. Aperture size is 5mmx5mm for solid lines and 5mmx3mm for dashed lines.

4. Conclusion

A new geometry based on the concept of gap waveguide has been proposed to allow the propagation of quasi-TEM modes in a rectangular waveguide within a wide band. The design is based in previous works which have used AMC on the walls of the waveguide to remove the cutoff condition, but the initial studies of the proposed modification provide for the first time enough bandwidth. Besides, the design has the advantage of gap waveguides of being a contact-less technology. The results can be seen as well as the horizontally-polarized version of the ridge gap waveguide. These are preliminary results and the possibilities and limitations of this geometry are currently being investigated.

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