Artificial Magnetic Conductors replacing absorbers for packaging of microstrip circuits

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Abstract

Artificial surfaces give boundary conditions that can be used for new applications improving the performance of different devices. When printed circuits are packaged in metal boxes, cavity modes are excited both from radiation in corners as well as from non linear devices. These modes can destroy the performance of the circuits and are typically handled by using lossy absorbers in the top layer of the metal box. However, if absorbers are replaced by Artificial Magnetic Conductors (AMC), the solution is much more interesting as the potential radiations are not absorbed but avoided. In this article we propose solutions of AMC lids made with compact unit cells valid for different frequency ranges.

1. Introduction

The necessary packing of microstrip circuit containing all type of active devices and discontinuities has to deal with the problem of exciting cavity modes as the metal of the box (upper lid) with the metal grounding the circuit allows the propagation of parallel plate modes. One typical way of dealing with these problems is by adding absorbers on the top lid which absorbe the radiated energy in discontinuities and this avoids the cavity modes. However, this method introduces losses on the circuits. Another interesting possibility can be given by using artificial surfaces. Inspired in the recently proposed contactless *gap waveguide technology* [1] that is based on the combination of AMC and PEC to remove parallel plate modes (see Fig. 1), we can use as well lids of AMC replacing smooth metal lids to avoid cavity modes. As illustrated in Fig. 1 if we use a lid with an AMC on top but at a small distance from the circuit the parallel plate/cavity resonances are avoided (whithin the frequency range given by the AMC), and no losses are added as there is no radiation from discontinuities or corners. The limit for this technique is the bandwidth of the AMC as well as its size and simplicity.

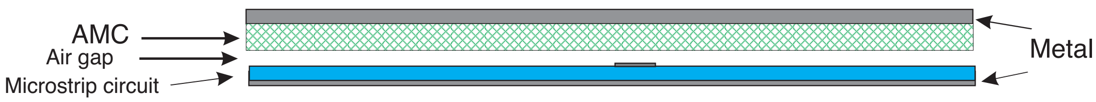

Fig. 1: Packaging of printed circuit with an AMC.

2. Selection of AMC for different frequencies

The selected AMC has to *react* to an electrical vertical field existing in between the two metal plates, for this reason we cannot use a totally planar AMC. Initially, we have studied different unit cell for the

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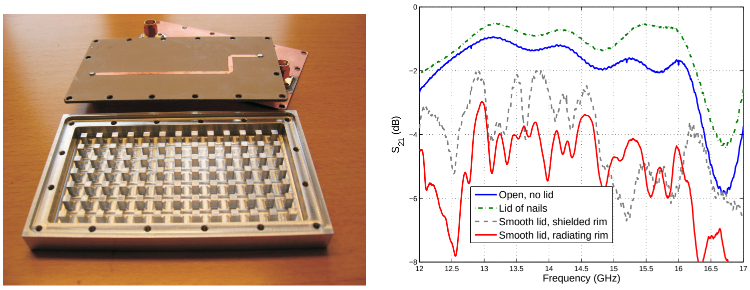
AMC such as pins, corrugations and mushrooms as candidates to do *gap waveguides* but as well to do packaging. Some of the results in terms of the achievable bandwidth for these unit cells are included in [2]. After that, we have demonstrated how the well-known "bed of nails" is very suitable to do packaging of microwave circuits at high frequencies within a wide band. We reproduce in Fig. 2 some of the results contained in [3]. In this example the targeted frequency is 15GHz.

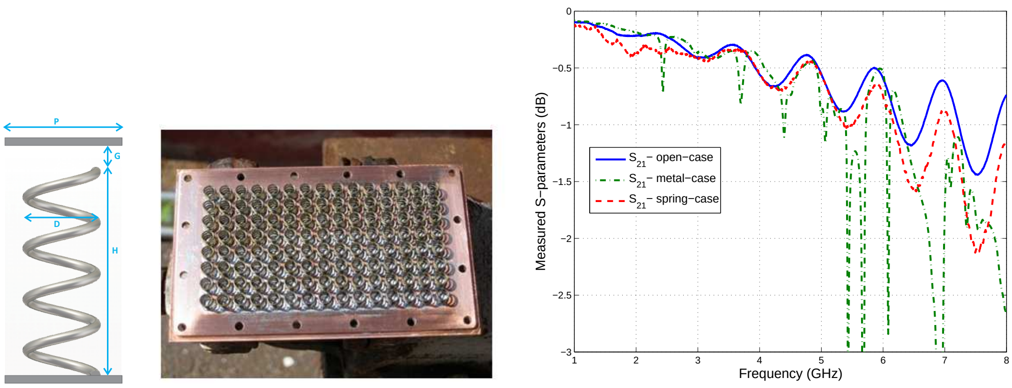


(a) Manufactured prototype (b) Measured S_{21}

Fig. 2: Bed of nails for packaging. Results taken from [3].

More recently we have successfully proposed to use the mushroom-type as a lid for packaging or either to surround the circuits with mushrooms as reported in [4].

In both cases it has been experimentally demonstrated that the S_{21} parameter for the circuit used as example (a simple bended microstrip line) is higher when packaged with such designed lids even when it is compared to the case of even unpacked circuit, as the lid of nails/mushrooms avoids radiation on bends. This proves also the advantage of the use of these structures in front of absorbers. Besides, a comparison with an ordinary smooth metal lid was also made in both cases. In such cases the excitation of cavity modes was evident. In both cases a 2:1 bandwidth was easily achieved.



(a) Unit cell (b) Prototype (c) Measured S_{21}

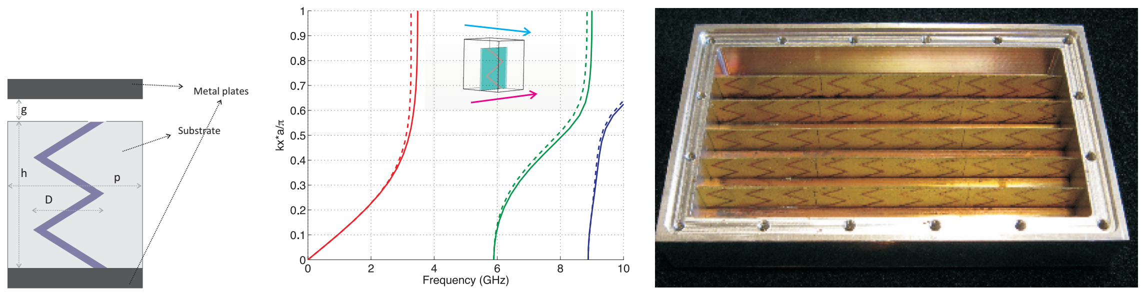
Fig. 3: Example of bed of springs from 3 to 6GHz N=2; H=5 mm, G=1 mm, P=6.13 mm, D=5.12 mm.

These solutions are appropriated for reasonable high frequencies but cannot be implemented at lower ones as the unit cell size will be too bulky in general terms, as for instance pins must be approximately $\lambda/4$ hight and mushrooms can be thin but require a relatively large surface as unit cell when printed in low permittivity substrates (to achieve good bandwidth).

3. Options for lower frequencies

When working at lower frequencies it would be of interest to have a unit cell for the AMC that is very compact both in height and periodicity, i.e., a small fraction of wavelength in both dimensions. One possibility is to transform the pins in springs as shown in Fig. 3. The example in the picture is able to get a bandwidth of 2:1 and with a very small electrical size. The different parameters of the unit cell such as radius, height, period or gap are used to achieve the desired frequency, but *grosso modo* one can imagine that the structure is similar to a pin that is twisted, so the straighten wire should have approximately the $0.25\lambda_0$ length to create the high impedance condition. The example was designed for 3 to 6GHz.

To overcome the manufacturing difficulties that springs have, we have recently designed a printed version of them that we named "zig-zag" unit cell in which the unit cell is printed on a slab as shown in Fig. 4 and several slabs are used in parallel. In this case we show the dispersion diagram where the stop band for any mode goes approximately from 3 to 6 GHz. The parameters to play with are described in the figure and the basis of operation are similar to the case of springs (derived from pins).



(a) Unit cell (b) Dispersion Diagram (c) Prototype

Fig. 4: Zigzag design for 3 to 6GHz N=3, p=10mm, D=7mm, h=10mm and g=2mm.

4. Conclusion

The use of different configurations of AMC as a lid for packaging of microstrip circuits has been proposed for different frequency bands. Experimental results show how they avoid the excitation of cavity modes as well as radiation losses and how compact unit cells can be designed for lower frequencies achieving bandwidths of 2 to 1.

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