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Artificial Magnetic Conductor from a Layer of Dogbone-Shaped Conductors over a Ground Plane

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Introduction

Artificial magnetic conductors (AMCs) have received considerable attention [1]-[3] because of their unusual reflection property and potential applications at microwave and millimeter wave frequencies [4][5]. Most AMCs are composed by a periodic conducting pattern based on a unit cell, printed on top of a substrate and backed with a metallic ground plane. This type of surface exhibits a resonance mode which enables the surface acting as an AMC.

In this work the reflection property of ground backed AMC layer composed by dogbone shaped conductors is investigated numerically and experimentally in a closed waveguide environment. Compared to other proposed AMC structure in the literature as [1] [6], the dogbone layer has the advantage that it can have a very subwavelength thickness and it does not require ground pins. The structure is analyzed both inside a waveguide and in free space. Full wave simulations are analyzed in both cases and the results are also compared with the one from an equivalent transmission line (TL) model based on modification of previous papers [6] [7]. Some preliminary results were also shown in [8] [9]. The results show that the phase of reflection coefficient is 0 degree at 6.4GHz. To further verify the result, measurement of reflection coefficient of triple dogbone element inside a C-band waveguide is also conducted. Though in this summary the AMC thickness is 2mm at 6GHz, results show that its thickness can be further reduced.

Simulated and Measured Results

The planar distribution of dogbone-like conductors is printed on a grounded dielectric, which in this summary is chosen to be foam. A very thin layer of kapton ($\varepsilon_r = 3.4$, thickness = 32μm) is used to support the dogbone conductors. The total substrate is thus formed by foam of 2mm thickness and the thin kapton layer. Dimensions of the dogbone unit cell are described in the caption of Fig. 1. Two kinds of simulations have been performed with HFSS. The first one is for an AMC layer with plane wave incidence when electric field polarized along the major axis of the dogbone. The second is for an AMC patch made by three dogbone unit cells inserted into a waveguide of dimensions W and H as given in Fig. 1. Both of them are printed on kapton and the 2mm thick foam.

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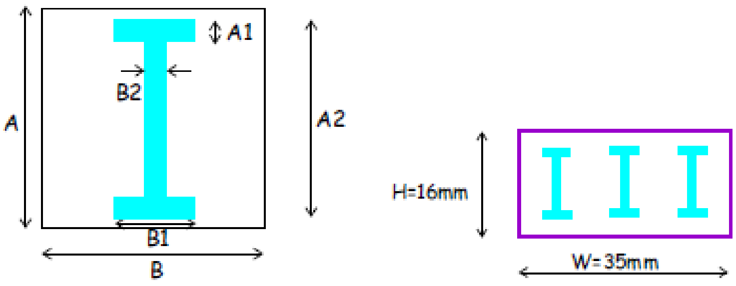

(a) Unit cell (b) Waveguide with dogbones

Fig. 1. (a) Proposed geometry: Dogbone unit cell made by a dogbone-shaped conductor over a dielectric spacer over a ground plane. (b) Three unit cells inside a standard C-band waveguide with dimensions A=H=16mm, A2=14mm, A1=B2=0.8mm, B1=4mm, B=W/3.

The parameter observed in these simulations is the phase of the reflection coefficient S11 at the reference plane, i.e., at the surface just above the dogbone layer. The phase is 0º when the surface behaves like an AMC, which happens at the magnetic resonance frequency [6]. We observe that the phase is 0º at 6.4GHz in both environments. The slope of the curves is related to the bandwidth of the magnetic resonance.

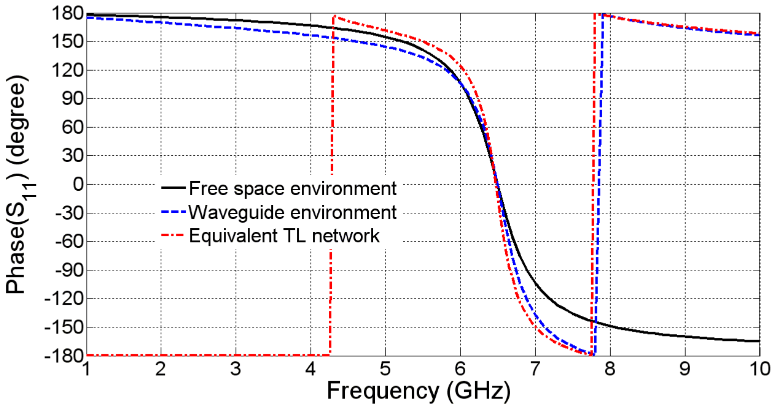

Fig. 2. Phase of the reflection coefficient at the surface of the AMC made of dogbones over a ground plane.

Concerning the measurements of the phase of the reflection coefficient, they must be comparative, since a direct measure of the phase of S11 includes the effect of the transition from coaxial line to waveguide. Hence, we performed two measurements, one with a short circuit termination in the waveguide and another one with the dogbone layer on foam pasted to the short circuit which acts as ground plane. Afterwards, we subtract the phases of the two measured S11 parameters. The results are shown in Fig. 3. The AMC behavior is clearly noticed, which occurs at a frequency slightly lower than the simulated one, probably due to manufacturing inaccuracies.

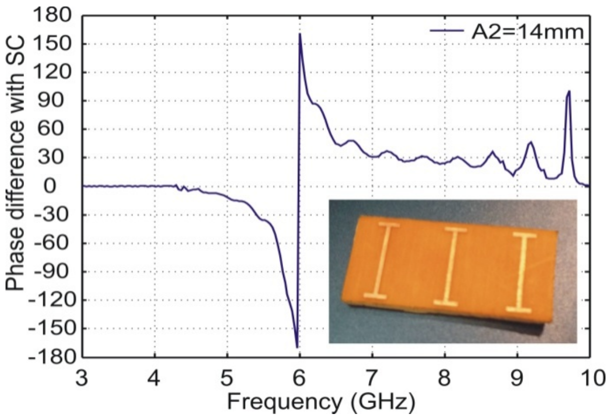

Fig. 3. Measurement of the phase of the normalized reflection coefficient at the surface of an AMC made of a dogbone conductors over a ground plane.

Models

Plane wave incidence on the AMC surface made by periodic dogbones on the grounded dielectric layer can be represented by the TL homogenized model in Fig. 4, which is obtained by applying symmetry relations to the model developed in [6]. The dogbone pairs in [6] exhibit both symmetric and antisymmetric resonances. However, because of the ground plane and image theorem, our AMC structure is equivalent to the antisymmetric mode supported in the dogbone pair in [6]. The values of L and C in the equivalent network (Fig. 4) representing the AMC are here found by curve fitting, i.e., the AMC resonance (also called magnetic resonance from [6]) is given by $f_m = 1/(2\pi\sqrt{LC})$, and then we match the impedance also at another frequency point. This leads to the parameters L = 1.09nH and C = 0.55pF. The phase of the reflection coefficient related to the homogenized TL and equivalent network, using these values of L and C, is shown in Fig. 2. The agreement with the simulated reflection-phases confirms that the topology of the equivalent network in Fig. 4 is correct.

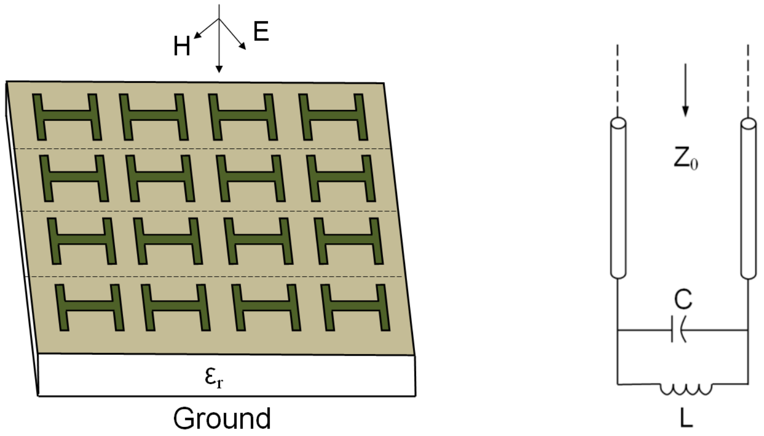

Fig.4. Equivalent model for a plane wave incident on the AMC surface represented as a lumped resonant load.

Finally, we want to mention that the value of the magnetic resonance can be estimated using the theory developed in [6]. Accordingly, a simple formula is given in [6], Eq. (8), which predicts the AMC behavior at the magnetic resonance f_m = 7.3GHz, which is however higher than 6.4GHz predicted in Fig. 2. However, it should be noted that the formula (8) in [6] neglects coupling with adjacent dogbones which is instead included in the results in Fig. 2. Nevertheless it can be used for initial designs of AMC surfaces.

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