Artificial Magnetic Conductor key angular stability parameters for improving antenna performance

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***Abstract*—This paper attempts to reveal the main features that should exhibit an artificial magnetic conductor (AMC), in terms of angular stability, to be optimally combined with an antenna aiming at improving not only the antenna's bandwidth, but also its radiation properties. The paper tries to provide a relation between the antennas radiation properties and the AMCs angular stability, through a study that combines two different AMCs, which exhibit different frequency deviations and stable bandwidths, with a patch based antenna.**

***Keywords*—Metasurface; Antennas; Artificial Magnetic Conductor; Angular stability**

I. Introduction

Many papers have been focused on combining metasurfaces with antennas to modify their radiation properties, such as their bandwidth, directivity, polarizability or beam direction [1]-[2]. However, the influence of the metasurface performance, in terms of angular stability and bandwidth, on the modification of these antennas properties have been rarely studied.

Consequently, this paper will be focused on analysing the characteristics that should exhibit a metasurface (specifically an artificial magnetic conductor (AMC)), in terms of angular stability, to improve the radiation performance of an antenna (patch antenna) when both are combined. Therefore, the paper will attempt to answer the following question: Is it crucial to consider an angularly stable AMC to enhance the antennas characteristics?.

II. Analysis of the AMCs

First of all, the angular stability of an AMC (HPAMC_C), which comprises hexagonal shaped patch based unit-cells, with lumped capacitors (see Fig. 1(a) capacitors in black) on a grounded RO4003C dielectric, will be analysed. The unit-cell geometrical parameters are: $p = 8.36, g = 0.5, w_e = 4.25$ and $w_C = 1.26$ (units in mm). A similar procedure as in [3] is followed to extract the capacitor value that provides a resonance in the interesting 5.8 GHz band, reserved for industrial, scientific and medical (ISM) applications. This value was concluded to be 0.1pF. It should be noticed that the gap between unit-cells was wisely chosen (1mm (2g in Fig. 1(a)) to fit commercially available capacitors of 0805 case size.

For comparison purposes, the same AMC, but without the capacitors (see Fig. 1(b)), will be also studied (HPAMC). For obtaining a resonance frequency at 5.8GHz, without modifying the unit-cell geometry or the grounded dielectric, the AMC unit-cell has to be enlarged and its dimensions have to be: $p = 11.83, g = 0.5$ and $w_e = 6.25$ (units in mm).

To analyse the angular stability of the proposed AMCs, the frequency deviation (Δ_f) and the stable bandwidth (B_s) parameters, previously defined in [4], will be numerically computed using the HFSS software. The results are shown in TABLE I. together with the unit-cells periodicities.

It can be concluded that the main reward for introducing lumped capacitors on the AMC is the broadening of its stable bandwidth and its miniaturization. The latter statement is in line with the conclusions extracted in a previous work published by the authors [3].

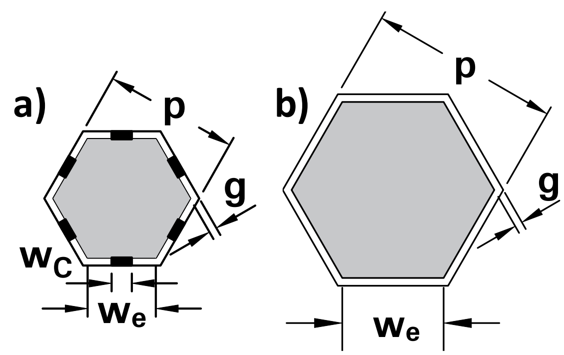

Fig. 1. Unit-cell geometry of HPAMC_C and HPAMC.

TABLE I. Angular stability comparison

Prototype	**Periodicity (mm)**	Δ_f (%)	B_s (%)
HPAMC_C	8.36	11.2	8.94
HPAMC	11.83	7.97	6.36

III. AMCs combined with antenna

A rectangular patch antenna on a RO4003C dielectric ($\epsilon_r = 3.38$ and $tan\delta = 0.0027$) of 0.8128mm thickness is adjusted to resonate at 5.8GHz. The geometrical dimensions of the antenna are: $p_x = 9.7, p_y = 18.75, L = 12.8, W = 17.25, W_g = 37.5$ and $L_g = 25$ (units in mm). This antenna will be regarded as reference antenna (PAR). Then, the antenna ground plane is replaced by the aforementioned AMCs resulting in PA+HPAMC_C and PA+ HPAMC, respectively (see Fig. 2 (a) and (b)). The feeding point and the length (L) and width (W) of the antenna patch are adjusted using HFSS, so that both PA+HPAMC_C and PA+HPAMC resonate at 5.8GHz. Therefore, the following geometrical parameters have to be used: $p_x = 8{,}8, p_y = 18.75, L = 9.22, W = 9.3, W_g = 37.5$ and $L_g = 25$ for PA+ HPAMC_C and $p_x = 8{,}8\,, p_y = 18.75, L = 9.32, W = 15.25, W_g = 37.5$ and $L_g = 25$ for PA+HPAMC (units in *mm*).

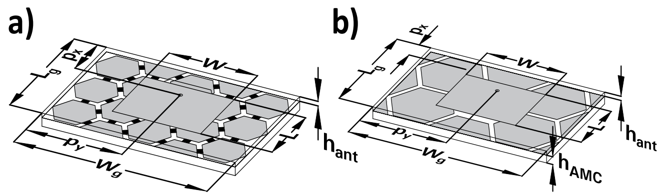

Fig. 2. Geometry of the PA+HPAMC_C and PA+HPAMC.

The behaviour of the resulting antennas, in terms of impedance matching (S_{11}) and radiation properties (directivity (D), gain (G), radiation efficiency (η) and front to back ratio (F/B)) at their resonance frequencies (5.8GHz), as well as their bandwidths (BW), are numerically computed and the results are detailed in TABLE II.

TABLE II. ANTENNAS RADIATION PROPERTIES

	PAR	***PA+HPAMC_C***	***PA+ HPAMC***	***PART***
h_T $[mm]$	0.8128	2.3368	2.3368	2.3368
S_{11} $[dB]$	-22.5	-22.2	-22.5	-22.8
BW $[MHz]$	117	394	166	336
D $[dB]$	7.7	7.6	6	7.6
G $[dB]$	7.4	7.6	5.8	7.5
η [%]	94	100	95	98
F/B $[dB]$	13.8	16.6	6.6	14.1

From the results one can draw two main conclusions: the first one is that the replacement of the ground plane by an AMC give rise to an enlargement on the antenna's bandwidth, which was also shown in other works [5]. However, what it is new is that an AMC with a wider bandwidth provides not only a much broader bandwidth, but also an improved radiation efficiency and front to back ratio.

For conducting an even fairer comparison the thickness of both the AMC ($h_{amc} = 1.524$mm) and the antenna ($h_{ant} = 0.8128$mm) are considered and hence, a new antenna is adjusted to resonate at 5.8GHz having a total dielectric thickness of 2.3368mm. The latter is not accounted by most authors since they usually consider that thick dielectrics are prone to propagating surface waves and deteriorating the radiation properties of the antennas. However, when considering a dielectric with a low relative permittivity and relatively thin, the latter fact may not be true. The results of this analysis are presented in the last column (PART) of TABLE II. From them, it can be once more confirmed that the previous statement regarding the use of an AMC with improved stable bandwidth gives rise to not only an enlargement of the antenna's bandwidth, but also an improvement of its radiation properties.

Finally, one can provide a brief answer to the question presented at the beginning of the paper. The AMC's angular stability influences the behaviour of the antenna when both are combined, but it is the stable bandwidth, instead of the frequency deviation, the parameter that provides a clear indication on the possible improvement of the antenna radiation properties.

IV. CONCLUSION

In this paper, the angular stability of two artificial magnetic conductors are analysed to check their influence when they are combined with antennas. It was shown that the stable bandwidth is a crucial parameter to not only enlarge the antenna bandwidth but also its radiation properties. Indeed, the increase of the AMC's grid capacitance brings about a widening of its stable bandwidth and hence, an improvement of the antennas radiation parameters and bandwidth when both are combined. Consequently, it can be concluded that the stable bandwidth is a more crucial parameter than the frequency deviation for combining AMCs with antennas aiming at improving the performance of the latter.

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