Comparative study on different AMC ground planes and its application to low profile wire antennas

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Abstract—*In this paper, the characteristics of three different types of artificial magnetic conductor (AMC) are investigated and compared: a mushroom-like surface, which is the classical example of AMC with connecting vias, and two surfaces with no vias, one of which is anisotropic. Both the simulation results and the measurements verify that the AMC behaviour is successfully accomplished around the resonant frequency. In order to complete the study, the characteristics of two different horizontal wire antennas placed above the surfaces are analyzed.*

Introduction

Artificial magnetic conductors (AMC), also known as high impedance surfaces (HIS), have been studied extensively in the last years [1-4]. These surfaces have unique properties in controlling the propagation of electromagnetic waves. Two of these properties are of special interest. First, they can behave as perfect magnetic conductors, so that the parallel image currents appear in-phase, rather than out-of-phase. This feature enables efficient radiation for antennas placed parallel and close to the surface. Second, they forbid the propagation of electromagnetic waves in certain frequency bands (electromagnetic band gap or EBG), so that there is an absence of multipath interference and radiation patterns are smoother. This is why, in this paper, they are going to be used to design low profile wire antennas, particularly, the horizontal dipole and monopole antennas.

The geometry of the HIS consists of a periodic metallization printed on a grounded dielectric slab. Metallic vias connecting the metallization to the ground can also appear. Considering both the influence of the type of metallization and the fundamental role of the vias for tailoring the AMC and EBG behaviour, the three surfaces that have been chosen to be studied are the mushroom-type surface [1], which is the classical example of AMC with connecting vias, the ring metallization HIS, with no vias, and the open ring metallization HIS, which has no vias either and is anisotropic.

AMC ground planes characterization

To completely characterize the three ground planes we are going to work with, both AMC and EBG behaviour will be analyzed. Depending on the geometry of the unit cell used to implement the high impedance surface, both behaviours may appear in the same frequency range [5].

Figure 1 shows the geometry of the three different unit cells, where the spacing between them, g, was determined as 2 mm. All metallizations are printed on a polyethylene substrate with dielectric constant of 2.2, loss tangent of 0.0004 and thickness of 5 mm. The radius of the metallic via of the mushroom is r = 0.25 mm and, in the case of the rings, a = 2 mm and $\alpha = 10^\circ$. Only the width is different in all cases, so that the frequency in which the reflected phases for all three cases are 0° can be fixed to the same value. Using a simulation tool (CST Microwave Studio) all surfaces have been designed to include in-phase reflection on their surfaces for a normally incident plane wave at 2 GHz.

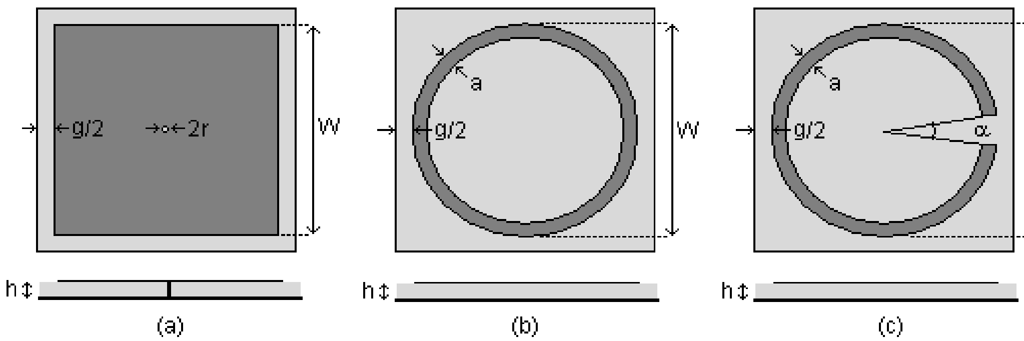

Figure 1. AMC unit cells.
(a) Mushroom-type (b) Ring metallization cell and (c) Open ring metallization cell

In order to fix the resonant frequency to 2GHz, the metallization width in each case must be, respectively, 20, 29 and 21 mm. This result indicates that the most compact structure is the mushroom-type one, because, for the same frequency value, its size is the smallest. Once known the size of each basic structure, the number of cells needed to implement each ground plane must be decided. In this case, to make the dimensions of all planes as similar as possible, N = 8, 5 and 7 has been respectively chosen.

Once the ground planes are completely designed, both the reflection phase and transmission coefficient S_{12} shall be studied. Reflection phase determines the range of frequencies in which the AMC behaviour is observed, and transmission, the range of frequencies corresponding to the electromagnetic band gap (EBG).

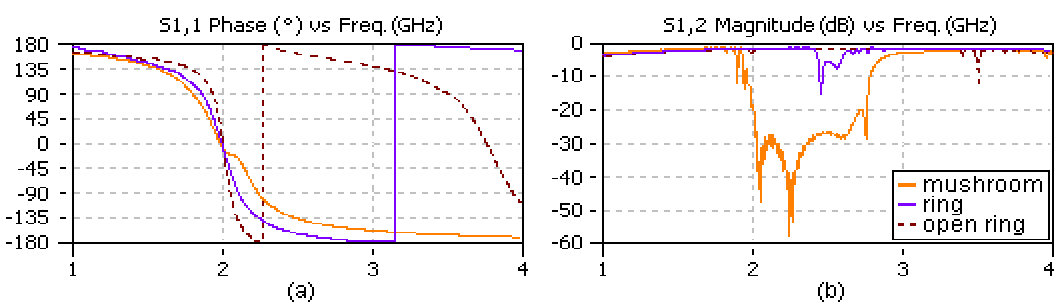

Figure 2. AMC and EBG behaviour.
(a) Simulated reflection phase and (b) Simulated EBG

Figure 2a shows the reflected phases of the three cases. For a frequency value of 2 GHz, in-phase reflection is observed in all cases. Something interesting about the AMC behaviour of the ground planes is that it is periodic, that is, the phase variations between $\pm 180^\circ$ are periodically repeated. Such period is smaller in the case of the rings.

Figure 2b corresponds to the simulated EBG. The mushroom-like plane presents a very noticeable EBG behaviour in the 1.9-2.75 GHz range. Both the AMC and the EBG behaviour occur in the same frequency range, something very positive taking into account that at 2GHz, apart from the fact that in-phase reflection exists, surface waves suppression is achieved. In the case of the rings, the EBG frequency range is quite small and does not occur in the same frequency range as the AMC behaviour. The absence of via is the determinant fact for this to occur.

Application to horizontal wire antennas

Normally, when above a conventional metallic ground plane, horizontal wire antennas radiate very poorly as the image currents appear out-of-phase, rather than in-phase and cancel the currents in the antenna. This situation improves when using an AMC surface as a ground plane. The horizontal dipole and horizontal wire antenna have been analyzed in order to confirm this fact.

The antennas design methodology consists of two basic steps. First of all, the optimal size of the antenna is calculated via simulation tool (CST). It is very important to slightly readjust the unit cells metallization size in case the resonant frequency is not exactly the desired one. Once known the antenna size which makes matching be maximum, the second step is determining its optimal height above the plane (see Table 1).

	Mushroom		**Ring metallization**		**Open ring metallization**	
	Length	Height	Length	Height	Length	Height
Horiz. dipole	$0.47\lambda_{2GHz}$	4 mm	$0.40\lambda_{2GHz}$	7 mm	$0.60\lambda_{2GHz}$	7 mm
Horiz. wire	$0.25\lambda_{2GHz}$	5 mm	$0.17\lambda_{2GHz}$	4 mm	$0.30\lambda_{2GHz}$	7 mm

Table 1. Size and height of the horizontal wire antennas.

The simulated return losses ($|S_{11}|$) of both the horizontal dipole and monopole antennas are plotted in Figure 3. In order to validate such results, the measurements corresponding to the horizontal monopole antenna have also been included.

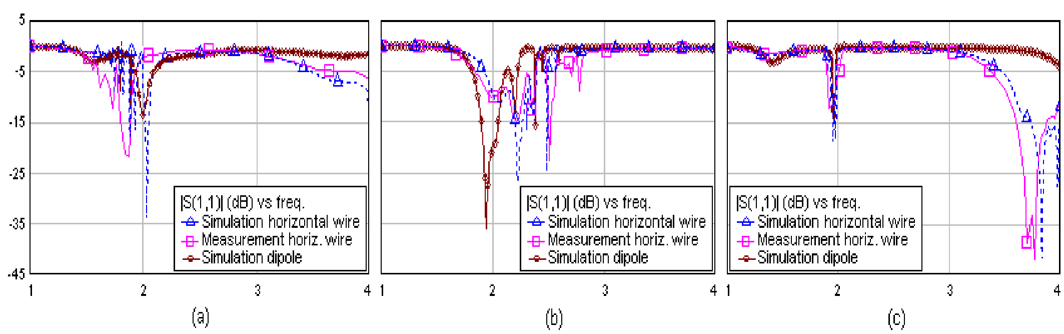

Figure 3. Simulated and measured horizontal wire antennas return losses.
(a) Mushroom based HIS (b) Ring metallization HIS and (c) Open ring metallization HIS

As it can be seen, the wire antennas on all ground planes are well matched with return losses below -10 dB, so most of the power is radiated. The resonant frequency of the simulation is 2GHz in all cases, practically the same as that of the measurement, with a good agreement.

Concerning the radiation pattern, horizontal wire antennas above AMC ground planes radiate very well in contrast to those above conventional metallic planes (see Figure 4).

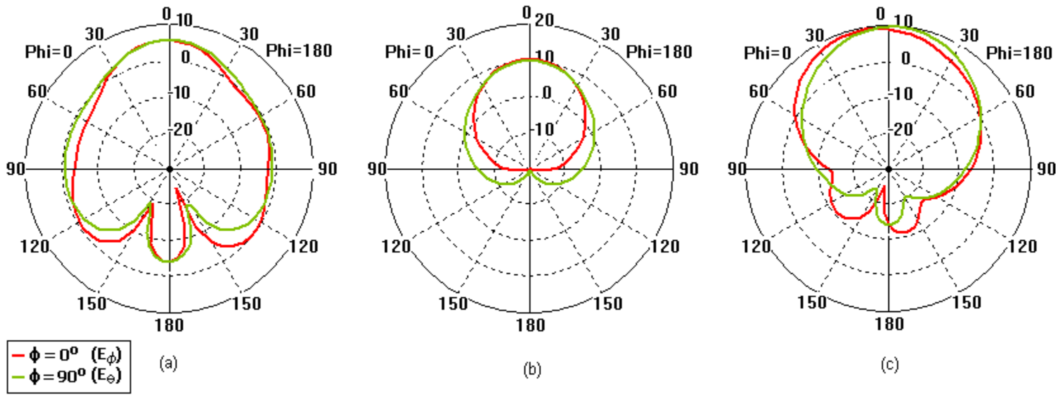

Figure 4. Simulated E-field radiation patterns of the horizontal dipole.
(a) Mushroom based HIS (b) Ring metallization HIS and (c) Open ring metallization HIS

Conclusions

Three different types of AMC structures have been investigated and compared: a mushroom-like surface, a ring metallization surface and an open ring metallization one, which is anisotropic. Regarding the ground planes characteristics, it has been verified that the AMC behaviour is successfully accomplished around the resonant frequency, as shows the fact that the reflected phases for all three cases are 0° in the desired frequency and also the fact that the horizontal wire antennas matching is maximum at that frequency. A clear electromagnetic band gap is observed in the mushroom-like HIS and because of the vias presence is this case, AMC and EBG behaviours occur in the same frequency range. On the contrary, ring-shaped metallization HIS hardly present an EBG. Finally, the horizontal wire antennas placed above the three AMC ground planes are well matched with return losses below -10 dB and also radiate very well in contrast to those above conventional metal planes.

References

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