

Optimal Design of Artificial Magnetic Conductors Including Angular Response

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Introduction

In recent years, different solutions have been adopted to realize AMC structures, both with mushroom surfaces [1] and by using planar Frequency Selective Surfaces (FSSs) [2-4]. These screens are suitable for low profile antenna configurations, especially in wireless communication systems [5]. In this work, a novel design methodology is introduced to derive Artificial Magnetic Conductor (AMC) screens with enhanced angular and frequency behaviours. The frequency and angular phase response are combined into a single two-dimensional map to visualize, in one single graph, the properties of the analyzed screen. The attention is also focused to the development of a genetic algorithm (GA) which allows the implementation of an AMC screen with unique characteristics, by adopting frequency selective surfaces (FSSs). The Frequency Band versus Incidence Angle (BIA) maps will be used to show the enhanced properties of screens synthesized by the GA in terms of angular stability and frequency response, implying a very good stability of the resonance frequency for a wide range of incident angles. In order to emphasize the reliability of our approach, a commonly employed structure will be also analyzed and the performances will be compared to that of our screen.

Synthesis of AMC screens including angular stability

As well known, an AMC is usually characterized in terms of the reflection coefficient Γ , by respecting the conditions $\text{Re}\{\Gamma_{AMC}\}=1$ and $\text{Im}\{\Gamma_{AMC}\}=0$ at the resonant frequency. This condition permits placing an electric source very close and parallel to the surface, improving the global efficiency and reducing the total device dimensions. It is important to underline that, to ensure a constructive interaction between the antenna and its image [5], the screen must exhibit the same resonant frequency for each spatial harmonic radiated by the source. However, the resonance depends also on the incidence angle, so that, from a practical point of view, it is necessary to fulfill the AMC conditions at a fixed frequency but with respect to the widest range of incidence angles. The design methodology has therefore to take into account the angular response of the screen. In our work, this goal has been accomplished by using a specifically derived GA

with a fitness function containing the angular response. In particular, two analyses have been performed, one in the frequency domain and the other one by varying the incidence angle at the central frequency of the band (see [3] for details). Indeed, the simultaneous use of both angular and frequency analysis in the fitness function proves to be an efficient strategy for designing AMC screens exhibiting a very stable resonance frequency with respect to the incidence angle.

BIA maps analysis

In order to characterize the AMC properties of a screen, we combine the frequency and angular phase response and visualize it into a single two-dimensional map. This chart takes into account the variation of the reflection coefficient phase, ranging within a frequency band and incidence angle interval from normal to almost grazing incidence of the impinging wave. In this way, a synthetic but complete description of the surface is obtained. Each point on the BIA map represents the phase of the reflection coefficient of the screen for a single frequency and a single angle of the incoming wave in the visible range. Therefore, this plot is suitable to highlight the unique characteristics of our AMC surfaces optimized by the GA. In order to prove the reliability and efficiency of our methodology, we have designed a screen to act as AMC at the frequency of 2.5 GHz. In this case, the design parameters involved in the optimization process are the shape and dimension of the FSS elementary cell, the permittivity as well as the thickness of the dielectric slab. As a result, we have obtained a square unit cell with a periodicity of 0.933 cm (the shape is shown in the inset of Fig.1 and Fig.2) and a dielectric substrate thickness of 0.15 mm on a PEC ground plane. The value of the slab permittivity, chosen by the GA, is equal to 32. In Fig. 1 and Fig. 2, we show the BIA maps of this screen for TE and TM polarizations, respectively. As apparent, all the information about the angular and frequency properties is included and easily readable. In this plots, we emphasize with a bold line (iso-phase line at 0°) where the reflected wave is in phase with the incident wave. It is important to note that this kind of analysis clearly shows the great stabilization of the screen at resonance. Next, we perform the same analysis for another solution presented in the open literature [7]; a periodic arrangement of square patches is considered, that has been proposed as AMC at 6.25 GHz. The square patch measures 0.9375 cm on each side, the periodicity is 1 cm; the dielectric substrate has permittivity equal to 3.5 and a thickness of 0.157 cm (the screen is shown in the inset of Fig. 3 and Fig.4). The BIA maps for this kind of structure are shown in Fig. 3 and 4. In this case, the resonance frequency is varying considerably with respect to the incidence angle. Conversely, the GA derived AMC screen exhibits a very stable resonant frequency, for both polarizations, even for angles close to grazing incidence, also if compared to other solutions [8]. In fact, if we consider the percentage deviation Δ of the resonance from the central frequency, this is negligible up to 88 degrees, still in the worst case (for TE polarization $\Delta=0.02\%$).

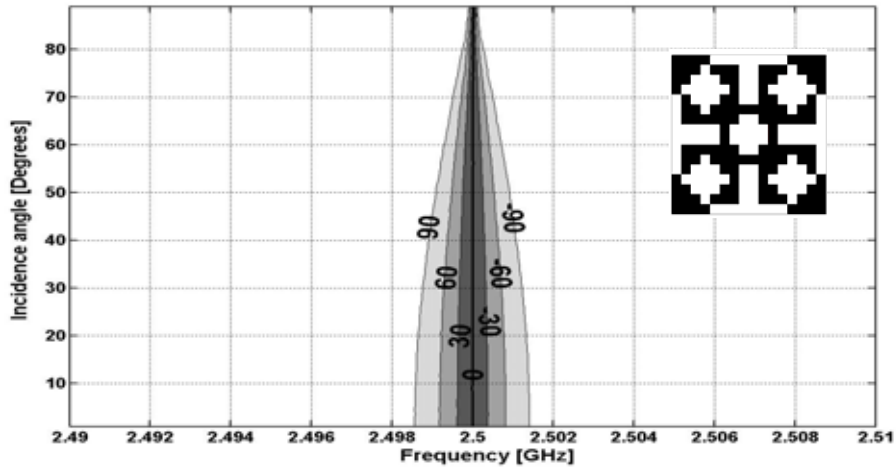


Fig. 1 - BIA map (isophase curves) for TE polarization of the screen with unit cell shown in the inset.

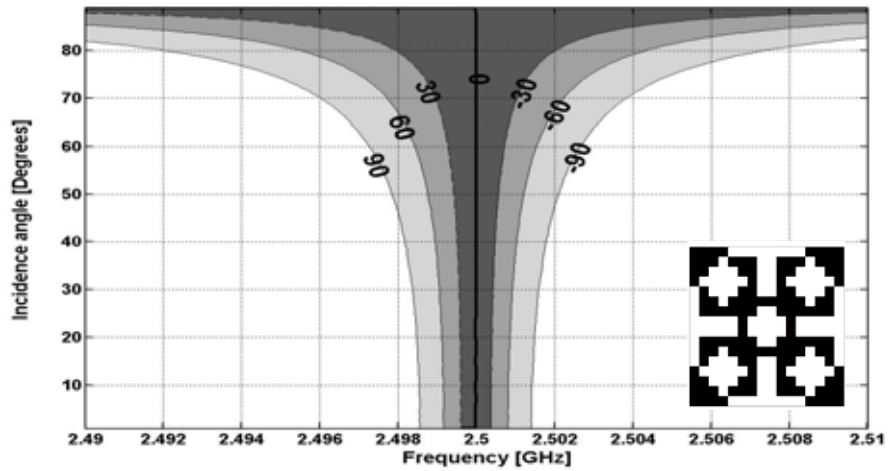


Fig. 2 - BIA map (isophase curves) for TM polarization of the screen with unit cell shown in the inset.

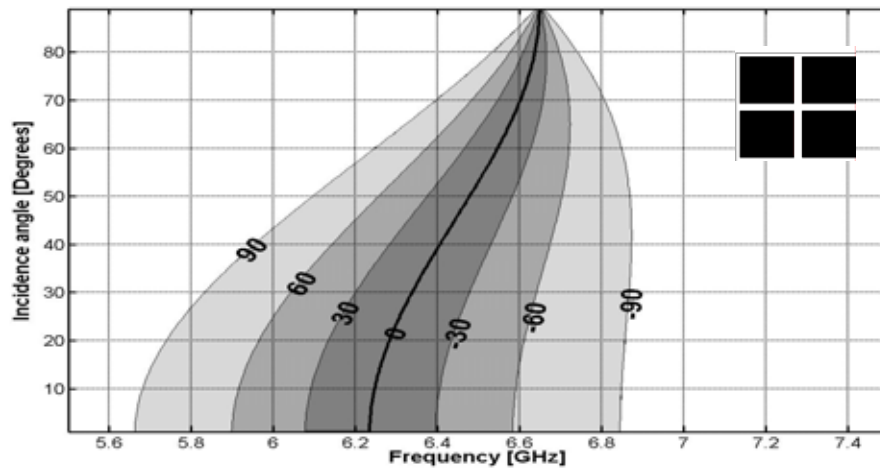


Fig. 3 - BIA map (isophase curves) for TE polarization of the screen with unit cell shown in the inset.

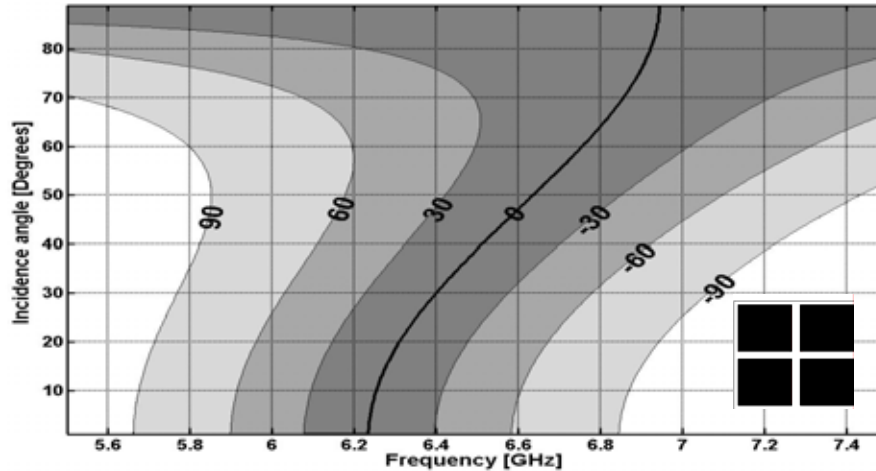


Fig. 4 - BIA map (isophase curves) for TM polarization of the screen with unit cell shown in the inset.

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