Multi layer artificial magnetic conductors for multiband antennas

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Abstract

In this paper we propose multi band reflectors based on high impedance surface (HIS). The HIS are composed of stacks of patches layers. The first part of this paper is about the design of a two-layer reflector and three-layer reflector. In a second part, performances of a multi layer HIS reflector is simulated using dipole antennas of different length. Finally the insertion of an inductive layer in the stack of capacitive layers of the HIS is discussed.

1. Introduction

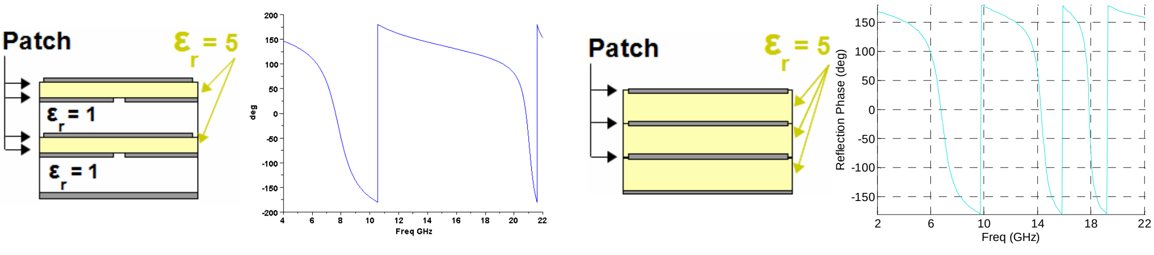
In recent years, a growing interest has been given to artificial magnetic conductors (AMC) and high impedance surfaces (HIS). Some practical antenna applications of these structures include directivity enhancement [1][2], reduction of radiating element mutual coupling [3], and the suppression of blind spots for phased arrays [4].

With the emergence of multifunction antenna systems, there is a growing need for the development of multi band AMC. Although much work has been carried out on this subject, recent investigations have been focussed mainly on the development of mono layer structures [5]. These structures are generally based on a single dielectric slab with an optimized FSS layer, which consists of multiple embedded and fractal like patterns to achieve multi resonant effects. However, very little investigation has been given to multi layer structures [6] [7], which can potentially offer extra degree of freedom to attain enhanced multi band performance.

In this paper, we propose novel multi band AMC designs based on a multi layer configuration. These developments are exposed with the objective of being used as reflectors for a printed dipole antenna. The study focused primarily in the 6-18 GHz band of frequency, which covers a large number of radar and communication systems.

2. Design of multi band HIS

AMC structures, which are discussed here, were designed with HFSS. The unit cells were placed between a couple of perfect electric conductor boundary conditions and a couple of perfect magnetic conductor boundary conditions to simulate an infinite AMC surface. In Fig. 1 (a) and (c), the unit cells of two multi band HIS are shown. They are composed of, respectively, two and three stacked capacitive layers aligned vertically over a ground plane and separated, respectively, with air and with dielectric material having a relative permittivity of 5.



(a) (b) (c) (d)

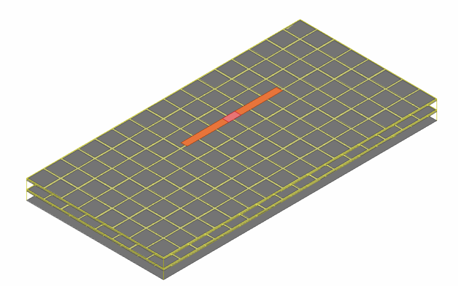
Fig. 1: (a) Unit cell of the dual-band HIS and (b) its reflection phase, (c) Unit cell of the three-band HIS and (d) its reflection phase

The structures provide multiple resonances, which can be adjusted with a proper dimensioning of the geometrical parameters. Here, the height of both structures is 1.5mm. Capacitive layers of the first one are two layers of patches really close (0.127mm). The size of the unit cell is 1.4mm x 1.4mm and the distance between the two layers is 0.75mm. Capacitive layers of the second HIS are just single layers of patches. The size of the unit cell is 3.4mm x 3.4mm, and the distance between each capacitive layer is 0.5mm. The first AMC structure resonates at two frequencies, 7.6GHz and 20.8GHz. The second AMC resonates at three different frequencies 6.8 GHz, 14.3 GHz, 17.8 GHz. The reflection phases of these structures are exposed on Fig. 1 (b) (d). To adjust the resonant frequencies, the patch size and separation distance between layers have to be optimized.

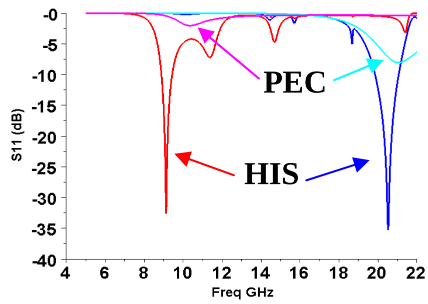
These stacks can be modelled by an equivalent circuit using Cauer Type I ladder network [7], dielectric or air slabs between patches layers are considered as series inductors and patch layers as shunt capacitors.

3. Antenna performance over a multi band HIS

To verify that the HIS design proposed can act as a reflector, a planar dipole antenna has been placed over the dual band HIS proposed previously. The distance between the dipole and the HIS is 1.5mm and the overall height (HIS+dipole) is 3mm. After optimization of the length l of the dipole, the antenna resonates at 9.1 GHz with l=13.4mm and at 20.5 GHz with l=6.2mm. Fig. 2 (b) shows the reflection coefficient of the two antennas placed over the HIS. For comparison purpose, these antennas have also been placed at 3mm above a perfect electric conductor (PEC).



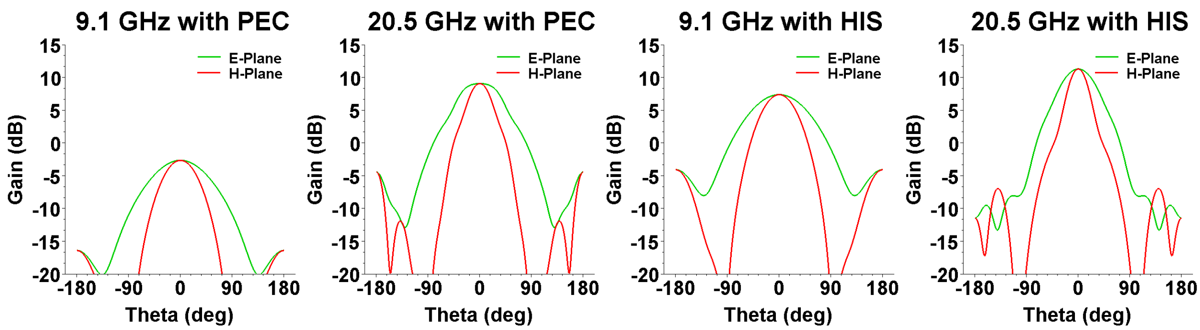
(a)



(b)

Fig. 2: (a) Dipole antenna over the dual-band HIS (b) S11 for two lengths of dipole, red: over AMC and l=13.4mm, blue: over AMC and l=6.2mm, magenta: over PEC and l=13.4mm, cyan: over PEC and l=6.2mm

The resonance frequency of the first antenna over HIS reflector is shifted above the first resonance frequency of the HIS. Moreover S11 shows some spurious mode near 15 GHz. These modes seem to be linked to the finite size of the HIS reflector 11.2mm x 22.4 mm. Fig. 3 presents the radiation pattern of the dipoles in the upper half space. With the multiband HIS reflector, gain levels are 7.5 dBi at 9.1 GHz and 11.5 dBi at 20.5 GHz. However, with a PEC reflector, gain levels drop to -2 dBi at 9.1 GHz and 9 dBi at 20.5 GHz. These results show the benefit of using the multiband HIS as a reflector.

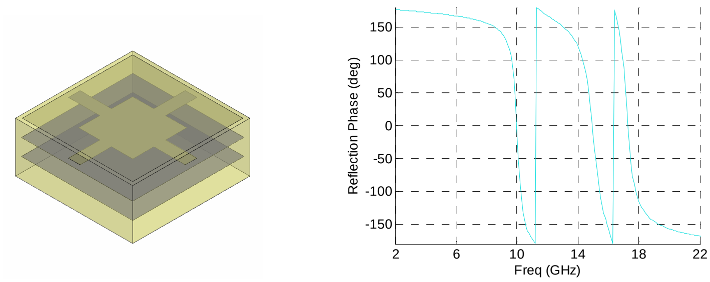


(a) (b) (c) (d)

Fig. 3: Gain of the antenna backed by a PEC (a) l=13.4mm, f=9.1GHz, (b) l=6.2mm, f=20.5GHz and the dual band HIS reflector, (c) l=13.4mm, f=9.1GHz, (d) l=6.2mm, f=20.5GHz

4. Role of an inductive layer in a multi band HIS

Conducting patch elements are considered as capacitive layers. An extra degree of freedom for the adjustment of the resonant frequencies can be obtained by inserting inductive layers in the design. The unit cell of a HIS design including an inductive layer is proposed, fig. 4. It is the same design as the first HIS proposed in this paper but a fourth layer is inserted between the first and the second patch layer. Inductive layers would be considered as shunt inductor in an equivalent circuit model.



(a) (b)

Fig. 4: (a) Unit cell of the HIS including an inductive layer and (b) its reflection phase

Here, the inductive layer is a grid of metal, unit cell is a cross. Fig. 4 (b) shows reflection phase of the new HIS. Similarly to the first proposed design, this modified HIS structure resonates at three frequencies (9.8 GHz, 14.6 GHz, 16.9 GHz). No additional resonances are observed, however, the first resonance frequency is shifted from 6.8 GHz to 9.8 GHz, and the others two resonances are slightly shifted. The insertion of the fourth inductive layer allows a better positioning of resonance in the 6-18 GHz band of frequency, and it can be used for optimization.

5. Conclusion

Multi band AMC reflectors comprising multiple stacked layers of patches have been proposed. These reflectors have been simulated close to a planar dipole antenna. It has been shown that the insertion of inductive layers in the AMC structure can help to adjust the resonance frequencies. Performances of the antenna over the reflector are good but the shift of resonance frequencies shows that both the antenna and the AMC structures have to be optimized together.

References

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