RADIATION PERFORMANCES OF A MULTIFREQUENCY DIPOLE ANTENNA ARRAY WITH A LEFT HANDED SUPERSTRATE

E. Sáenz[1)], R. Gonzalo[1)], I. Ederra[1)], P. De Maagt[2)]

[1)] Electrical and Electronic Engineering Department, Universidad Pública de Navarra, Campus Arrosadía, E-31006, Pamplona, Navarra, Spain. E-mail: ramon@unavarra.es, elena.saenz@unavarra.es
[2)] European Space Research and Technology Centre, ESTEC, PO Box 299, 2201 AG Noordwijk, The Netherlands. E-mail: Peter.de.Maagt@esa.int

Abstract - In this paper, the radiation performances of a multifrequency antenna array (MFAA) which consists of two dipoles (1 and 3) that are radiating at 9.57 GHz and other one (dipole 2) radiating at 11.98 GHz are presented. In order to improve the directivity and to reduce the coupling between the dipoles, a non-uniform Left Handed (LH) superstrate formed by cells of different resonant frequencies has been placed over them. Each dipole is tuned to the resonant frequency of the cells that are on top of it allowing the power transmission and producing a very uniform illumination that enhance the radiation performances of the whole structure. With this configuration, directivity values of 10.1 dB when dipoles 1 and 3 are radiating and 8.1 dB when dipole 2 is radiating have been obtained, with a gap between dipoles of 0.23 λ_0 at resonant frequency of the first dipole and a coupling smaller than - 17 dB.

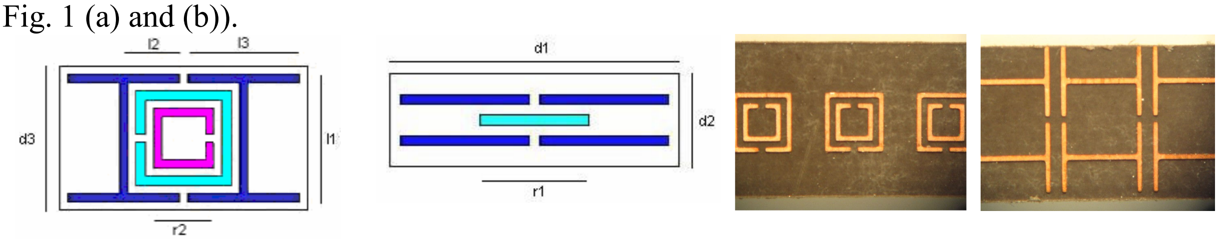
Introduction

Nowadays, the study of the so-called metamaterials (MTMs) has developed a lot. Examples of MTMs include Photonic Band Gap (PBG) structures and Left Handed Media (LHM). Several recent papers have exposed the usefulness of these MTMs for different applications [1]-[8]. LHMs can be understood as resonators with pass band and stop band properties at which the power is transmitted or reflected respectively. Up to now, volumetric MTMs have been used to create Artificial Magnetic Conductor (AMC) for antenna applications [5]. Working in the rejection bands as substrate of dipole antennas instead of a perfect electric conductor (PEC) ground plane, an enhancement of the directivity and reduction of the back radiation is obtained. Recently, applications of LHMs have shown the benefits of their pass band properties using them as superstrate of planar antennas with the goal of improving their radiation behaviour [5-8].

In this paper a MFAA formed by three dipoles, two of them tuned to a fixed frequency and other one tuned to a different frequency, is analysed. Over each dipole, a group of left-handed cells with the same resonant frequency of the dipole has been placed, forming a superstrate that confines the power radiated by this dipole and improve its radiation performances, especially the directivity, efficiency and back radiation. Due to the pass band properties of the cells, they will allow the transmission of power of the dipole that is tuned to its resonant frequency, reflecting the power radiated by the other dipole. With this configuration the dipoles can be very close but reducing the coupling between them.

LHM Media

The type of left-handed unit cell selected to create the LHM media is the ones described in [3, 4]. It consists of one SRR between two pairs of CLSs all embedded in a dielectric slab (see Fig. 1 (a) and (b)).



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

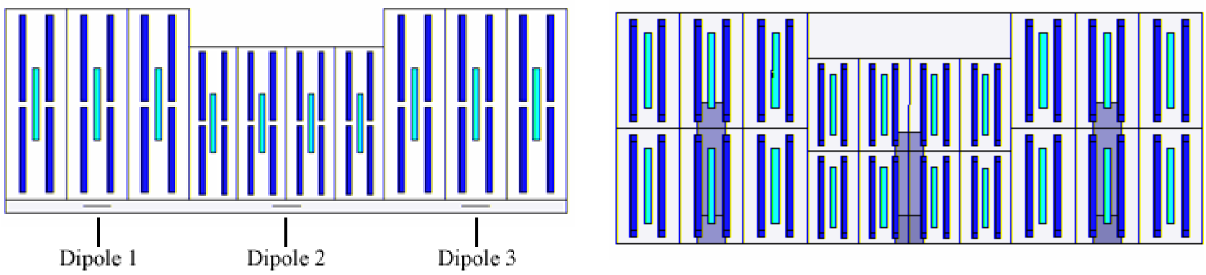
Fig.1. Geometry of the LHM unit cell. (a) Front view (b) Top view (c) Detail of the SRRs (d) Detail of the CLSs

In order to create a multifrequency superstrate, LHM working at two different frequencies (9.57 and 12.40 GHz) were designed. In particular, the high-resonant-frequency (HRF) unit cell will be 0.8 times smaller than the low-resonant-frequency (LRF) one. Both cells were fabricated by using a layer by layer technique with the purpose of verifying their performances. A detail of these layers can be observed in Fig. 1 (c) and (d).

Geometry of the Multifrequency Antenna Array (MFAA)

Placing these cells explained in the previous section on top of dipoles tuned to the resonant frequency of the cells, a MFAA can be designed. Each group of cells will allow the transmission of power of the dipole to its resonant frequency and will reflect the power radiated by the other dipoles. With this configuration, dipoles can be very close and with low coupling between them.

In this case, the MFAA is formed by two dipoles (dipole 1 and 3) tuned to 9.57 GHz, the resonant frequency of the LRF cell, and one dipole (dipole 2) tuned to 12.40 GHz, the resonant frequency of the HRF unit cell. Three periods of the LRF cells are over the dipoles 1 and 3 and four periods of the HRF cells are over the dipole 2. The configuration of the MFAA with LH superstrate is shown in Fig. 2. The distance between dipoles d_{12} and d_{23} is 7.322 mm, that is $d_{12}=d_{32}=0.2335\ \lambda_0$ at 9.57 GHz ($d_{13}=0.4671\ \lambda_0$) and $d_{21}=d_{23}=0.302\ \lambda_0$ at 12.40 GHz.



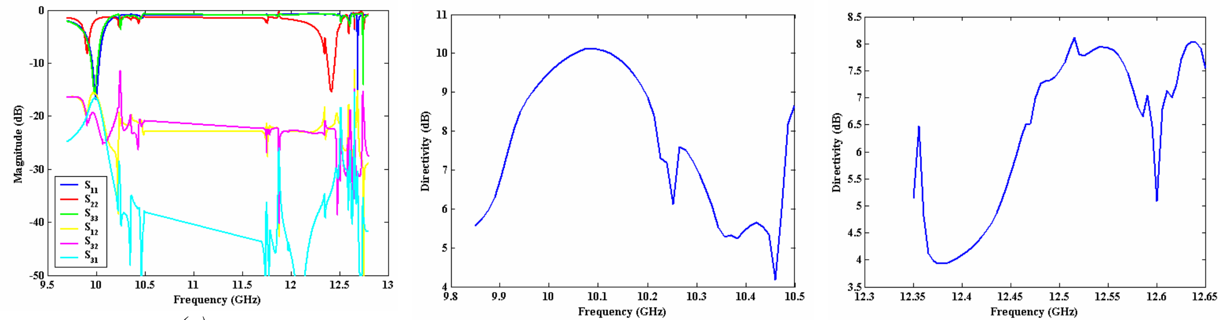
(a) *(b)*

Fig. 2. Geometry of the MFAA with LH superstrate (a) Front view (b) Top view.

Radiation Performances

Once the MFAA is designed, the radiation performances in terms of S parameters, E field, directivity and radiation patterns of the configuration are going to be analysed.

First of all, the S parameters of the antennas have been studied showing a good impedance matching and low coupling between dipoles. Due to the load of the superstrate, the resonant frequencies of the dipoles have shifted slightly, being 10 GHz in the case of the dipoles 1 and 3 and 12.42 in the case of the dipole 2. The impedance matching values obtained in all cases are around - 17 dB with couplings between them at resonant frequencies smaller than – 17 dB. These results can be seen in Fig. 3 (a).



(a) *(b)* *(c)*

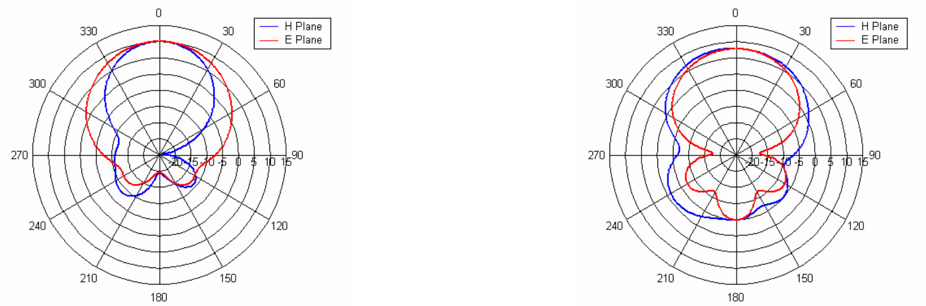
Fig. 3. (a) S parameters. (b) Directivity when dipole 1 and 3 are radiating (c) dipole 2 is radiating

Drawing the E field at the H plane of the dipoles, a very uniform illumination of the radiating surface can be observed. Besides, when the dipoles 1 and 3 are radiating, only the

LRF cells that are over them allow the transmission of power. As the HRF cells that are between the the dipoles 1 and 3 do not allow the transmission of power, the power radiated by the dipole 1 cannot be received by the dipole 3, reducing the coupling between them. On the other hand, when the dipole 2 is radiating, only the HRF cells are transmitting the power.

Due to this uniform illumination, a very high apperture efficiency is achieved obtaining also high directivities. When the dipoles 1 and 3 are radiating, the higher directivity value obtained is 10.11 dB at 10.084 GHz (see Fig. 3 (b)) and when the dipole 2 is radiating the maximum directivity is 8.11 dB at 12.51 GHz (see Fig. 3 (c)).

Plotting the H and E planes radiation patterns at the frequency of maximum directivity (see Fig. 4) it can be observed how the power radiated by the dipoles is absorbed by the superstrate and radiated to the bore-sight direction. As a result, the back radiation is reduced and the directivity increased. Besides, symmetrical H and E patterns are obtained.



(a) *(b)*

Fig. 4. H and E plane radiation patterns (a) Dipole 1 and 3 (b) Dipole 2.

Conclusions

In this paper a MFAA with a left-handed superstrate has been presented. The array is formed by two dipoles tuned to the resonant frequency of the LRF cells that are on top of them (9.57 GHz) and one dipole tuned to the resonant frequency of the HRF ones (12.40 GHz). Although the dipoles are very close ($d_{12} = d_{32} = 0.2335\ \lambda_0$ at 9.57 GHz), the coupling between them is smaller than - 17 dB. Due to the uniform illumination of the radiating surface, the directivity values obtained are 10.11 when the dipoles 1 and 3 are radiating and 8.11 when the dipole 2 is radiating, which result in 100% aperture efficiency.

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