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Size influence of checkerboard-like wideband metamaterial absorbers

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Abstract

Recently the performances of radar absorbing materials have been extended by designing new thin structures with wideband properties and large angles of incidence [1]. In this paper, the design and performances of such ultra-wideband microwave absorber of low thickness material developed within the framework of the SAFAS project (self-complementary surface with low signature) are confirmed with complementary quasi monostatic measurements and finite array simulations using Finite Element Tearing and Interconnecting domain decomposition methods (FETI).

1. Introduction

The innovative nature of the SAFAS project is based on the combined use of a self-complementary chessboard-like structure, a metasurface, and a WAIM layer, to make possible a dual polarized self-complementary connected array antenna [2] and, also, an ultra-wideband and wide-angle metamaterial absorber. The architecture of the absorber material that has been optimized in [3] is presented in Figure 1 and Figure 2. The lower part is the self-complementary structure (checkerboard) which inherently has a wideband behavior. The elementary cell of the absorber is given in Figure 2, where the metallic parts are drawn in grey. To achieve the absorption of the structure, resistive deposits were placed between each conducting patch of the checkerboard. This self-complementary structure is placed above a ground plane. To increase the bandwidth of the structure, a metasurface also using resistive deposit has been optimized and is located above the checkerboard. Finally, to minimize the impedance discontinuity between the absorber and free space and to provide wide angle and wideband frequency matching, a WAIM layer has been added at the top of the structure.

In this paper, additional simulations results of the absorber performances for several finite sizes of the array are presented. The simulations using the FACTOPO code developed at ONERA and equipped with a FETI-2LM solver ([4]) are carried out on High Performance Computer (HPC) provided by the GENCI consortium in France (Grand

Equipe National en Calcul Intensif). New measurement results obtained with CAMERA@ONERA measurement facility are also presented to confirm the simulated predictions.

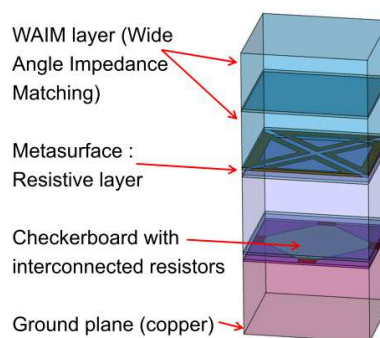


Figure 1: Multilayer absorber description (unit cell).

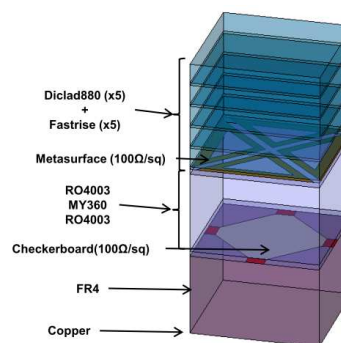


Figure 2: Nomenclature of each layer of the ultra-wideband absorber

2. Results and discussion

The absorber is composed with Copper as ground plane, Epoxy FR4 (glass-reinforced epoxy laminate, $\epsilon_r = 4.7$, $\tan \delta = 0.02$), RO4003 (woven glass reinforced hydrocarbon/ceramics, $\epsilon_r = 3.38$ and $\tan \delta = 0.0027$) from Rogers, MY360 (woven glass PTFE, $\epsilon_r = 2.33$ and $\tan \delta = 0.0011$) from Neltec and Dielad 880 (fiberglass reinforced

PTFE-based composites, $\epsilon_r = 2.2$ and $\tan \delta = 0.0009$) from Rogers. The checkerboard is constituted by metallic patches etched on RO4003 material and connected at their corners with Resistor Foil NiCr (100 ohms per square) from Ticer Technologies. The metasurface is composed with the same Resistor Foil NiCr (100 ohms per square) etched on the second RO4003 material. The total thickness of the absorber is 11.5 mm.

Other material choices were possible but not reachable in the time line of the SAFAS project. It is therefore not an optimum but a compromise to validate a proof of concept. The prototypes having the following dimensions (20 cm²) and composed of 1600 cells were manufactured by CIRETEC (Figure 3). The simulations results presented in Figure 4 are obtained with ONERA’s FACTOPO_fem-feti domain decomposition code [4]. The exact size of the array prototype 20 cm² fabricated with 1600 unit cells is simulated as well as virtual prototypes of 10 cm² (400 cells) and 30 cm² (3600 cells). These parametric studies on the size of the array show that the performances of the absorber are already obtained with a limited size of 10 cm². It is also observed a convergence of the RCS reduction in terms of bandwidth and magnitude starting from a prototype of size 20 cm².

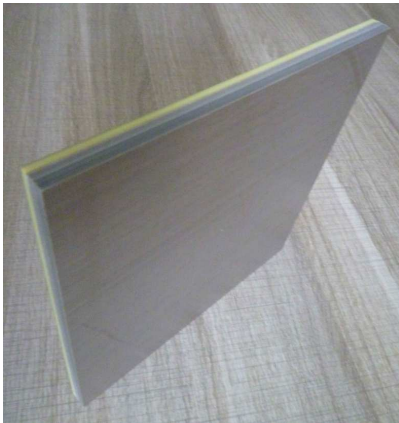


Figure 3: Prototype of the manufactured absorber.

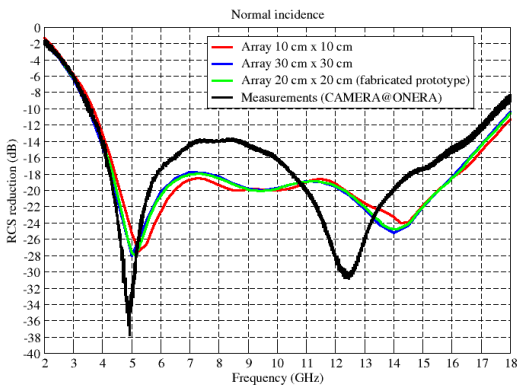


Figure 4: Finite array simulation results and measurements of the checkerboard-like absorber

Similar to what has been observed in previous works [1], at normal incidence (Figure 4) the FACTOPO@ONERA finite arrays simulation results give a bandwidth (-10dB) of 3.5-18 GHz while the CAMERA@ONERA measurement results give 3.7-17.5 GHz. These results seem different from each other but the behavior of the absorber is well observed on a very large bandwidth. The level of the two characteristic minima appearing at 5 GHz and 14 GHz in simulation is shifted around 4.9 GHz and 12.5 GHz in measurements. This frequency shift can be explained mainly by the cause of a poor estimation of the dielectric constants. The FR4 material is a low cost material and the dielectric constant is subject to significant fluctuations. This work seems to exclude the influence of the finite dimensions of the absorber in these frequency shifts. The level of the magnitude of the reflection coefficient between these two minima is higher in measurements than in simulations, and a poor estimation of the dielectric constant can also be the cause. Finally, it should be noted that these differences occur between -14 dB and -18 dB which are intrinsically low values.

3. Conclusions

New simulation results and complementary measurements of the SAFAS prototype presented in this paper confirm the overall performances of the absorber. These works are actually transposed to the domain of composite materials in the framework of the SAFASNAV project.

Acknowledgements

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