URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Wide-angle and polarization insensitive metamaterial absorber for C-band

X. Lleshi*(1,2), T. Q. V. Hoang(1), B. Loiseaux(1), and D. Lippens(2)
(1) Thales Research and Technology, Palaiseau, France, xhoandri.lleshi@thalesgroup.com
(2) Institute of Electronics Microelectronics and Nanotechnology, Lille, France; didier.lippens@univ-lille.fr

Extended Abstract: Metamaterial absorbers (MMAs) are an arrangement of artificial elements able to convert the electromagnetic energy into thermal energy by exploiting the dissipation of the materials [1]. In 2008, Landy *et al.* introduced the first manufactured MMA with an absorptivity of 88% experimentally demonstrated at 11.5GHz [2]. Since then, various MMAs over the whole electromagnetic spectrum from microwave to optical have been presented in the literature. Recently, the advent of the 3D printing, which offers the possibility to fabricate arbitrary 3D geometries without machining, has increased the degrees of freedom in designing and in the choice of materials. A fully 3D-printed metal-dielectric multilayer absorber is demonstrated in [3]. In this work, we present a wide-angle and polarization insensitive MMA which is designed to be manufactured using the Fused Deposition Modelling (FDM) technology and to operate in C-band.

The proposed structure is a periodic array of identical multilayer pyramids. Each pyramid is composed of 15 circular resonant cavities made of conductive and dielectric filaments. The conductive filament is Electrifi with σ=17000S/m, while the dielectric filament is Preperm DK8 with ε_r=8 and tanδ=0.004. The high value of permittivity is used to enhance the angular robustness. The perfect symmetry of the circular shape offers the polarization insensitivity of the structure. Each cavity of radius *a* absorbs the resonant frequency f_0:

$$f_0 = \frac{c\chi'_{11}}{2\pi a\sqrt{\varepsilon_r}} \quad (1)$$

where *c* is the speed of light in free space, χ'_{11} represents the first zero of the first-order Bessel function $J_1(x)$ and ε_r is the relative permittivity of the dielectric layer.

The period of the unit cell is 16.3mm, the width of the cavity at the bottom is 14.3mm and decreases to 6.5mm for the cavity at the top. The contribution to the absorption is related to the dissipated power in both dielectric and conductive filaments. The high losses in both materials cause a reduction in quality factor but enhance the frequency bandwidth and thus provide a flat absorptivity over the frequency band. However, in order to ensure a high absorptivity over the whole frequency range of interest, the thickness of the cavities (i.e. dielectric layer) were optimized to satisfy the condition of unitary absorption, which is then adjusted from 0.7mm at the bottom to 0.3mm at the top. The thickness of the conductive layers is fixed at 0.3mm due to the printing constraints. The total thickness of the structure is 12.2mm, corresponding to $0.24\lambda_0$.

The simulations under normal incidence show an absorptivity above 97% for the entire C-band of 4.1-8.0GHz for any polarization, confirming the polarization insensitivity of the proposed MMA. The angular insensitivity with an absorption level greater than 90% remains stable up to 53° in TE mode for the whole C-band. In TM mode, the angular behavior is less robust: an absorptivity above 90% can only be achieved up to 24°. The reason is linked to the different excitations of the surface currents. Stronger currents are excited in TE mode as the magnitude of the electric field does not change with incident angle, whereas weaker currents are excited in TM mode due to the decreasing electric field in oblique incidences.

With such interesting performance, the proposed MMA can be exploited in different applications such as radar cross section reduction, anechoic chamber, electromagnetic interference reduction, etc.

This work has been partly funded by the DGA. The authors would like to thank Carole Jégou, Philippe Pouliguen and Sylvain Gransart for helpful technical discussions.

References

[1] C. M. Watts, X. Liu, and W. J. Padilla, “Metamaterial electromagnetic wave absorbers,” *Advanced Optical Materials*, **24**, 23, pp. OP98-OP120, May 2012, doi: 10.1002/adma.201200674.

[2] N. I. Landy, S. Sajuyigbe, J. J. Mock, D. R. Smith, and W. J. Padilla. “Perfect metamaterial absorber,” *Physical Review Letters*, **100**, 207402, May 2008, doi: 10.1103/PhysRevLett.100.207402.

[3] X. Lleshi, T. Q. V. Hoang, B. Loiseaux and D. Lippens, "Design and Full Characterization of a 3-D-Printed Hyperbolic Pyramidal Wideband Microwave Absorber," in IEEE Antennas and Wireless Propagation Letters, **20**, 1, pp. 28-32, January 2021, doi: 10.1109/LAWP.2020.3037718.