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Additive Manufacturing for Item Identification

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Abstract

Additive manufacturing processes, and in particular fused filament fabrication, are proposed to realize a novel class of passive devices able to tag items by using the electromagnetic fingerprint for encoding the desired information. An example for a parallelepiped resonator is shown to clarify the proposed concept.

1. Introduction

Additive manufacturing (AM) has been considered since the beginning as an invaluable tool for rapid prototyping, thanks to its cost-saving feature for small production batches if compared to more expensive injection molding process, and for its intrinsic capability of almost endless customization [1], [2]. The benefits of this new technology has been exploited in a wide range of applications, spanning from aerospace, automotive, medicine, building [3]. However, recent advancements and concepts in this area are also suggesting the steaming new directions that were considered unfeasible or not profitable, namely large scale production [4], [5].

One of the challenges in current production paradigms is the need to univocally identify or, at least, classify an object. The tagging of an item can be seen as a fingerprint associated to it that can assist the logistic operations but may also serve for anti-counterfeiting purpose. Different solutions are currently available whose most common examples are probably represented by optical barcode and Radio Frequency Identification (RFID) [6]. In addition to these mature technologies, a quite recent alternative that has been object of extensive investigation is represented by the chipless RFID tag. This device does not use any Integrated Circuit (IC) and in the vast majority if its implementations does not resort to batteries or other electronic. A chipless RFID is generally fabricated with standard industrial Printed Circuit Board (PCB) processes and it is therefore an almost bidimensional object [7]–[9]. The chipless RFID concept has also been further explored in order to add a sensing function [10]–[15].

An interesting merge of the degrees of freedom offered by additive manufacturing processes and the simplicity of the chipless tag concept could lead to the fabrication of the tag directly inside the object (with a seamless integration of both functions and roles) or conveniently embedded into products realized with other processes. The benefits of this paradigm in a field such as the anticounterfeiting one can be remarkable and further enhanced if synergically used with other security layers both hardware (*e.g.* optical) as well as software (*e.g.* blockchain)

The current investigation describes the ongoing activity of designing a fully three-dimensional chipless RFID tag completely realized with additive processes. The final shape may vary depending on the employed material, the application, the available volume, the hosting object and desired final cost.

2. Three dimensional chipless RFID tag design

The proposed chipless RFID tag is a fully three-dimensional object that can be implemented in various shapes or even integrated directly into the tagged item (Figure 1). The reflection coefficient measured by a probe is the frequency response of the resonators that can be exploited as its spectral signature.

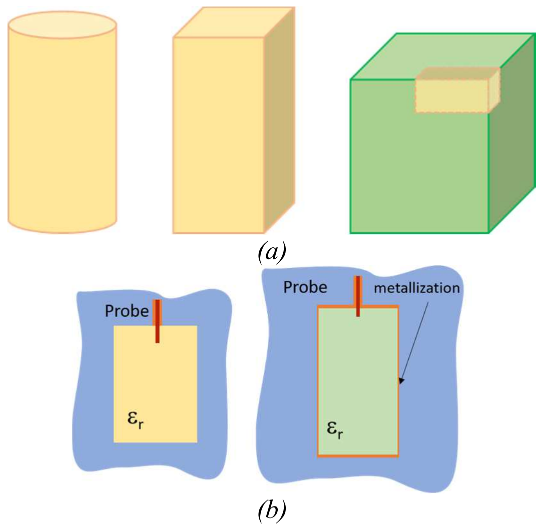
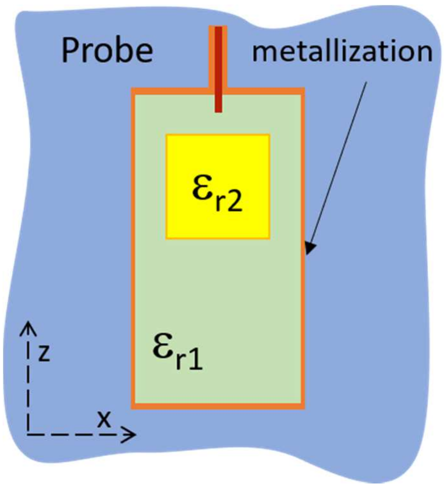


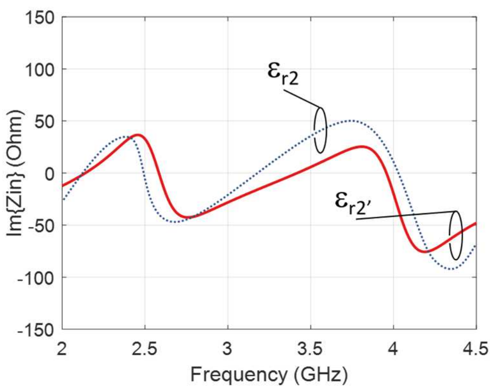
Figure 1. Example of different shapes and configurations of three-dimensional chipless RFID tags (a) and reading process by using a probe coupled to open/metallized resonators.

The tag shape and material determine the frequency response and, in particular, the resonant frequencies. The evaluation of the resonances of a dielectric resonator has already been exploited for dielectric antennas [16] or filters [17] and in some cases it is possible to analytically calculate the resonance modes. However, for non-trivial geometries it is necessary to resort to numerical investigations.

In the envisioned application, it is important to encode the information in the frequency response of the resonator and therefore a multi-resonance structure is the most suitable one. The strategy adopted to shape the electromagnetic signature consists in modifying the physical structure of the resonator by exploiting the features offered by additive manufacturing processes that allow to easily fabricate the chipless RFID which, in turn, would be rather complex with subtractive approaches. An example is reported in Figure 2 where a metallized cylindrical or cuboidal tag fabricated with a material with permittivity ε_{r1} hosts an inclusion of a different material with permittivity ε_{r2}.



(a)



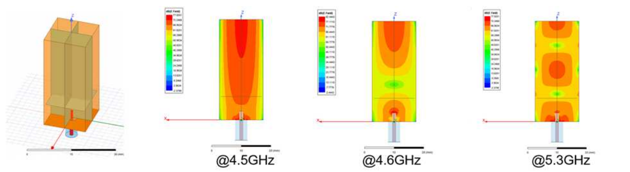
(b)

Figure 2. (a) Representaiton of the nested strucutre of the proposed chipless RFID tag consisting of a main hosting structure realized with a dielectric of permittivty ε_{r1} and an inclusion of a different material (permittivity ε_{r2}) and (b) expected variation of the frequency response for different material inclusions.

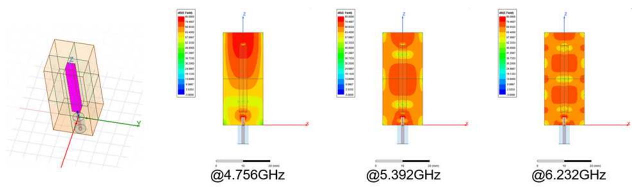
3. Preliminary results

A preliminary investigation of this concept has been carried out by considering a resonator with a parallelepiped shape. The size of the resonator is 1.5 cm x1.5 cm x3.45 cm. Two types of inclusions are considered: a thin axial inclusion along the main axis characterized by a size of 5 mm x5 mm x 3 cm, a wide inclusion located in the central part of the resonator with reference to the z direction (1 cm x1 cmx 5mm). The material used for the inclusion is air and the outer surface is metallized with the only exception if a small hole for the probe insertion. Three electric filed distributions are reported for each case to highligth the frequency shift caused by inclusions of different dimensiona and placement (Figure 3). The inclusion effect seems to shift upwards the resoances of the unperturbated fully-filled resoantor. It is important to underline that the void inclusion can be realized without a particular effort by using additive amnufacturing processes whereas other approaches, such as subtractive ones would require a second phase for assembling (*i.e.* gluing the two parts).

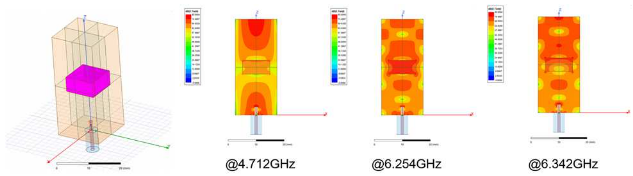
Finally, the imaginary part of the input impedance is reported for three different tags to show the multiple resonances that can be exploited for the encoding function. Ongoing activity is devoted to maximizing the number of encoded states in a small volume and to the realization of prototypes for assessing the expected performance with measurements.



(a)



(b)



(c)

Figure 3. Examples of resonance frequencies variation depending on the shape and position of the inclusion: (a) no inclusion, (b) thin axial inclusion along the main axis and (c) wide inclusion located in the center part of the resonator. Three electric filed distributions are reported for each case.

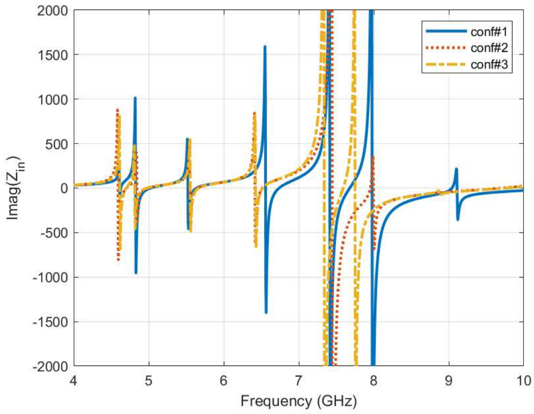


Figure 4. Example of variation of the resonances of the three dimensional RFID tag as a consequence of different inclusion configurations.

4. Conclusion

A novel approach for designing seamless integrated resonators inside additive manufactured objects with the aim of associating an identification code to the object is presented. The code is encoded in the frequency domain electromagnetic response of a probe inserted in a suitable position of the object. An example for a parallelepiped resonator is shown to clarify the proposed concept.

4. Acknowledgements

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