Thin smart multilayer microwave absorber based on hybrid structure of polymer and carbonated nanoparticles

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Abstract – A thin multilayer sheet was created in order to absorb electromagnetic waves in the GHz range. Submillimetric conductive and dielectric layers based respectively on carbon nanotubes and polymer were successively stacked. This smart periodic arrangement with increasing charges concentration shows an especially high absorption index despite its overall millimetric thickness.

Electromagnetic sources have grown considerably these last decades. Telecommunication systems and radars emit waves within a specific frequency range into the environment. However metallic structures crossing the propagating wave disturb signal by deflecting or reflecting it. As typical example, civil and military radars operating air traffic control are disturbed by parasitic echoes from wind turbines. For this reason, a prohibited area for wind turbines spanning hundreds of square kilometers is delimited around each airport. A way to avoid signal deterioration is to prevent echoes from troubling structures by an efficient absorber. This paper presents a thin microwave absorber based on carbon nanostructures, more specifically carbon nanotubes (CNT) and a dielectric polymer. The polymer confers interesting mechanical properties to the device because of its strength, flexibility and easy thermoformability. The CNT network is obtained by depositing a waterborne CNT-based ink (AquaCyl™) on a polycarbonate substrate. Recent studies show the potential of this type of approach to create conductive patterns over dielectric substrates [1] for e.g. flexible electronics purpose [2]. In this work, the commercial CNT ink is modified in order to tailor the conductivity by adjusting the density of CNT network.

An efficient absorption requires a combination of low transmission and low reflection. A weak transmission is obtained if the material has a high conductivity σ. The desired conductivity level is reached thanks to a network of CNT. The conductive layer is obtained by dip-coating of a suitably diluted AquaCyl™ ink on a surface-modified sheet polycarbonate [3]. The dilution level controls the amount of nanotubes covering the surface. Hence the resulting σ-value is controlled by ink concentration. Besides, reflection must remain weak to optimize absorption. For this reason, the absorber is a multilayer alternating conductive and dielectric layers. The dielectric layer is a pure polycarbonate sheet selected for its low ϵ-value of 2.8 for GHz range, preventing excessive reflection from air/dielectric interfaces [4]. Thereby this metamaterial combines a high conductivity and a low permittivity. Absorption index A depends on reflection and transmission of power which are described by the S-parameters formalism used for the measurement configuration, detailed in ref [4]. S_{11} and S_{22} correspond to reflected power ratio respectively at port 1 and port 2 (Fig. 1). S_{21} corresponds to transmitted power ratio from port 1 to port 2 and inversely for S_{12}. The absorption equation of wave incoming by port 1 is the following:

$$A_{1\rightarrow 2} = 1 - |S_{11}|^2 - |S_{21}|^2 \tag{1}$$

Reflection level increases with the conductivity σ of each conductive layer. Instead of stacking identical layers, it is possible to create a concentration/conductivity gradient by varying σ-value of successive conductive layers [5]. Assuming for convenience that the stack of conductive layers is organized to show an increase of conductivity from port 1 to port 2, the incident wave at port 1 firstly meets a poor conductor involving a small reflection. As the electromagnetic wave passes through the multilayer, the reflected part back towards port 1 increases but this happens inside the material, where conductive layers on the incoming port 1 side can absorb it. It follows that the overall reflection is decreased what improves absorption index as shown in Fig. 1. The full line curve gives the absorption index for a measurement from port 1 (close to the lower conductivity layer), whereas the dotted line gives the measurement in the opposite direction from port 2. The second curve shows a worse absorption meaning that the material can control the propagation direction. Moreover, the separation of the curves accentuates as the number of layers increases as demonstrated by Fig. 1(a) with 3 conductive layers compared to Fig. 1(b) with 5 conductive layers.

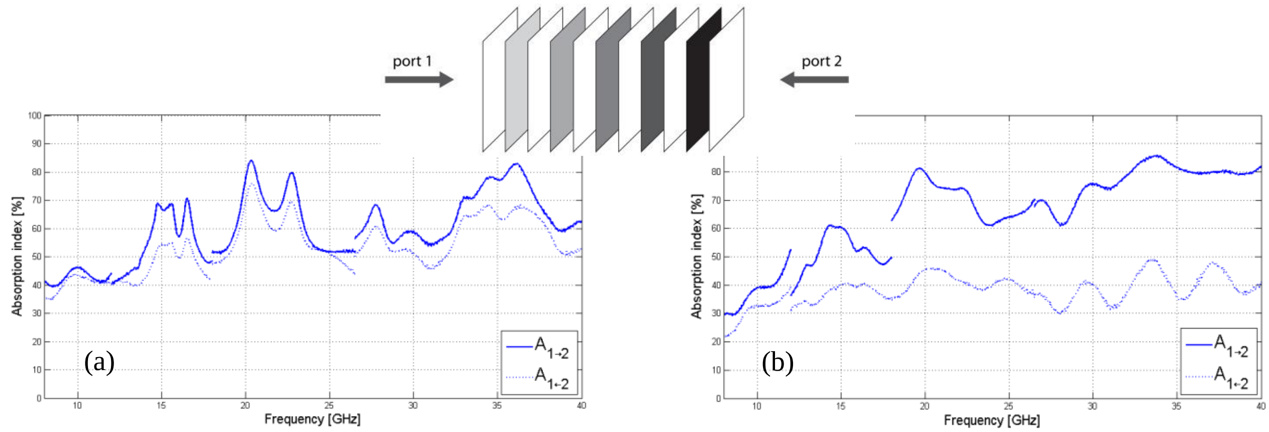

Fig. 1 – A gradient arrangement of conductive layers (grey) separated by dielectric layers (white) shows a better absorption from port 1 to port 2 (full line) than the opposite direction (dotted line). The sample (a) is composed by 3 conductive layers 125µm thick surrounded by 4 dielectric layers 110µm thick. The sample (b) is composed by 5 conductive layers (125µm) and 6 dielectric ones (110µm).

Current samples open prospects for new metamaterials that would fit into several applications thanks to their small thickness and easy conformability. It is therefore quite conceivable to cover the elements disturbing electromagnetic propagation. Another emerging focus is related to privacy issues, i.e. signal confinement inside buildings to secure wireless data transmission.

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