Evaluation of a Buckypaper's Electromagnetic Shielding Efficiency in X Band

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Abstract— Carbon nanotubes (CNTs) properties and applications are one of the most innovative and interesting research areas in physics and engineering. The electromagnetic behaviour of CNTs composites and plastic material such as PE and PMMA has been analized in several works. Recent works have highlighted how CNTs can be effectively applied in electromagnetic interference (EMI) as high shielding material. Basically, this is due to their high aspect ratio and their tunable conductivity, which allows the electrical percolation (with a little number of CNTs). It is crucial to understand and control the electromagnetic properties of these materials to apply them to devices design in several research fields. A buckypaper is a thin sheet made only with an aggregate of CNTs. A potential application is in shielding technology to protect electronic devices from electromagnetic interferences: for istance CNTs shields could be applied to avoid radar detection of militar aircrafts, or to prevent equipment damaging and unintended setting modication. At the same time, CNTs shields could be applied to avoid radar detection of militar aircrafts. Moreover, in the next years these structures could have a wide application in nano- and bio-science: potential application in the electromagnetical shielding concern nanoelectronis devices, nano-biomedical imaging and sensing or, in the near future, the protect medical equipments from high-frequency radiations. This paper studies the shielding efficiency of a buckypaper interposed between a multifrequency source and a electromagnetic waved detector. Our analysis is focused only on X Band frequencies.

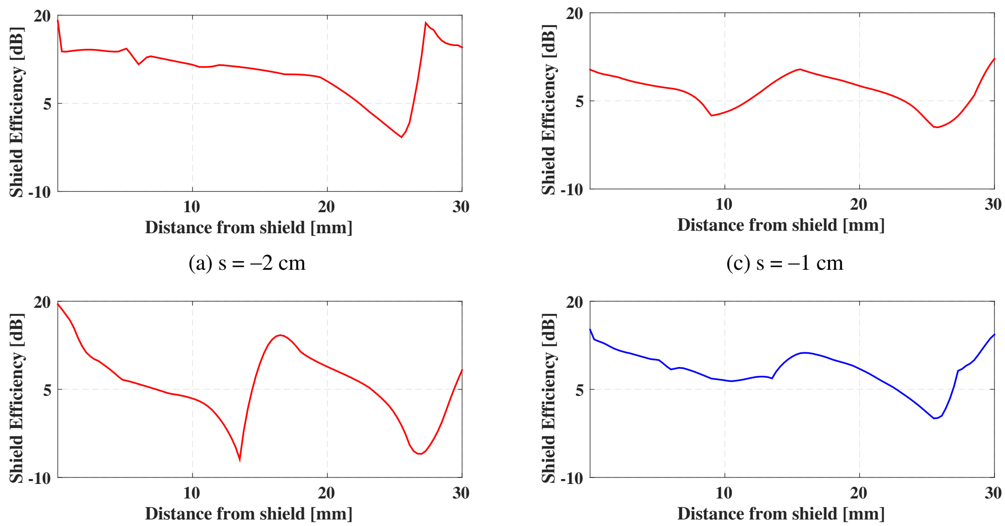
1. INTRODUCTION

In recent years, a quick spread of wireless technologies and electronic devices led to a significant growth in terms of electromagnetic emissions within the environment, urging to find new solutions to solve various issues, including electromagnetic interference (EMI) [1]. This problem affects various branches, such as the industrial and commercial sector, and it also influences people's private life and effectively, most people are familiar with portable electronic devices, such as mobile phones. A field in which electromagnetic interference represents a severe issue is the physician-hospital one. The instrumentation which is used within hospitals and clinics constists of many electronic devices (active and passive), which might be affected by interference phenomena, due to waves generated by themselves or by other nearby devices. Thus, reduction of EM emissions is to be considered a main goal to achieve. Since a reduction in terms of intensity, regarding emissions irradiated by the source, is not always achievable, neither worthwhile, it comes as no surprise that the interest of the scientific community for EMI shielding devices is growing constantly. Despite a large number of different EM screens is present in literature, new shielding tecnologies are being developed by scientific community. Since the appearance of the first carbon nanotubes (CNT) devices, it was thought to use them in various applications due to electrical and mechanical characteristics, and one of these is their use in the shielding of EM radiation [2]. This article proposes a project of a screen of CNT buckypaper. The model of this structure has been simulated using ANSYS HFSS software.

2. MATERIALS AND METHODS

A buckypaper is a CNT aggregate [3]. Such a struture is too complicated to be simulated, so it has been chosen to realize a simplified model which consists of an omogeneous layer with the same electrical characteristics of a buckypaper [2]. CNT's parameters in the 8–12.4 GHz band have been considered and they have been inserted in HFSS. A spire with radius $r = 3$ mm and thickness $t = 0.15$ mm has been assumed as field source. It has been design as a toroid made of PEC, and deprived of a small part in which the excitation port will be placed. The power on the excitation port has been set to 1 KW in order to evaluate high shielding values. A first simulation without the shield has verified the actual operation of the source, after the shield design has been started. The shield is placed at the center of an air box of $6 \times 6 \times 12$ cm, the spire is 5 mm distant from the shield. The shield edges touch the box ones to avoid undesidered fields on the measuring point.

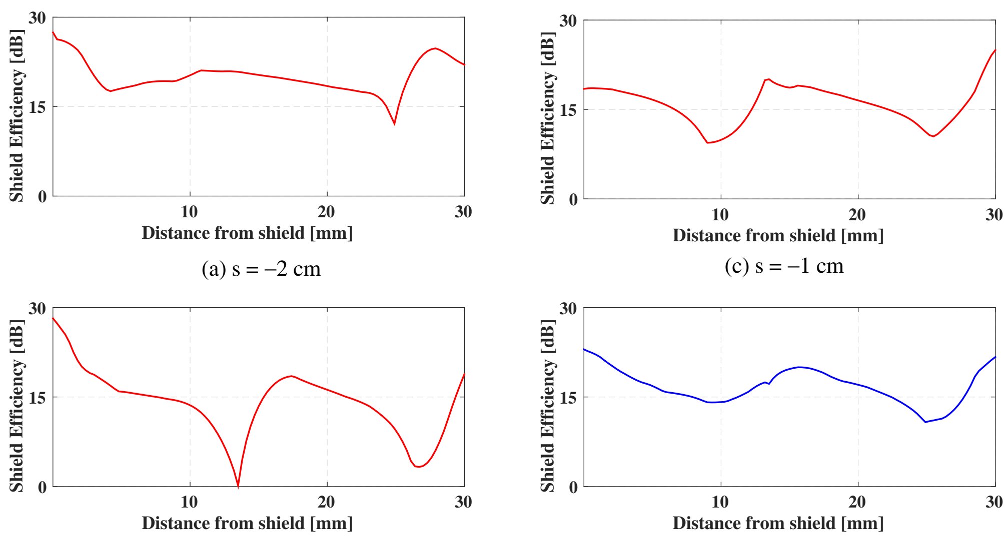
The working frequency is set to 9 GHz. The simulation consists in the evaluation of the shielding efficiency given different source's distances and different shield's thicknesses. After, also the working frequency is been varied. Moreover, a second simulation consisted in two buckypapers spaced by an air gap.



(a) s = −2 cm (c) s = −1 cm

(b) s = 0 cm (d) avarage

Figure 1: SE evaluated in differents positions of the 5 µm shield, (a) is the SE for $s = -2$ mm, (b) is the SE for $s = 0$ mm, (c) is the SE for $s = -1$ mm, (d) is the SE for the avarage values of SE.



(a) s = −2 cm (c) s = −1 cm

(b) s = 0 cm (d) avarage

Figure 2: SE evaluated in differents positions of the 20 µm shield, (a) is the SE for $s = -2$ mm, (b) is the SE for $s = 0$ mm, (c) is the SE for $s = -1$ mm, (d) is the SE for the avarage values of SE.

3. RESULTS

3.1. Single Screen

The field measurement has been along the screen with a step of $s = 1$ cm between two successive points, centered at $s = 0$ cm. The field intensity is has been evaluated at a depth between 0 and 3 cm. For reasons of symmetry, the graphs show the shielding efficiency measured only on the right side of the screen. The results report the shielding efficiency in dB. The following results have been obtained by analyzing the shielding efficiency averaged over the points of evaluation, and by varying the shield tickness w.

With $w = 5\,\mu\text{m}$ (Fig. 1(d)), the shielding efficiency varies between 0 and 15.5 dB (respectively evaluated at a distance of 0 and 25.1 mm)

With $w = 20\,\mu\text{m}$ (Fig. 2(d)), the shielding efficiency varies between 11 and 23 dB (respectively evaluated at a distance of 0 and 25 mm)

With $w = 50\,\mu\text{m}$ (Fig. 3(d)), the shielding efficiency varies between 16 and 25.8 dB (respectively evaluated at a distance of 0 and 25 mm)

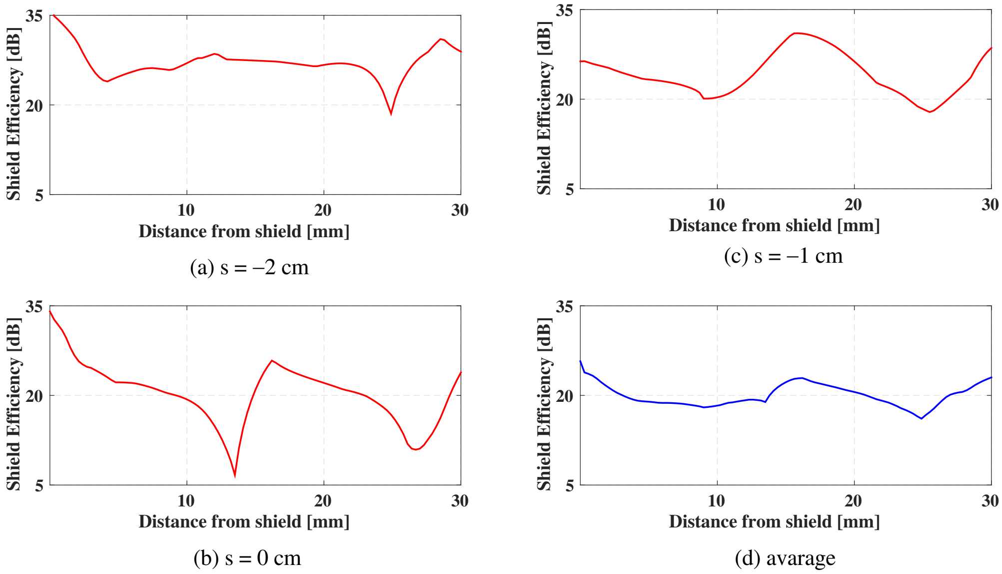


Figure 3: SE evaluated in differents positions of the 50 μm shield, (a) is the SE for $s = -2$ mm, (b) is the SE for $s = 0$ mm, (c) is the SE for $s = -1$ mm, (d) is the SE for the avarage values of SE.

3.2. Double Screen

The second simulation regards the two buckypapers case (Fig. 4(d)). It has measured a shielding efficiency which vary between 9 and 18.7 dB respectively evaluated at a distance of 0 and 25.1 mm.

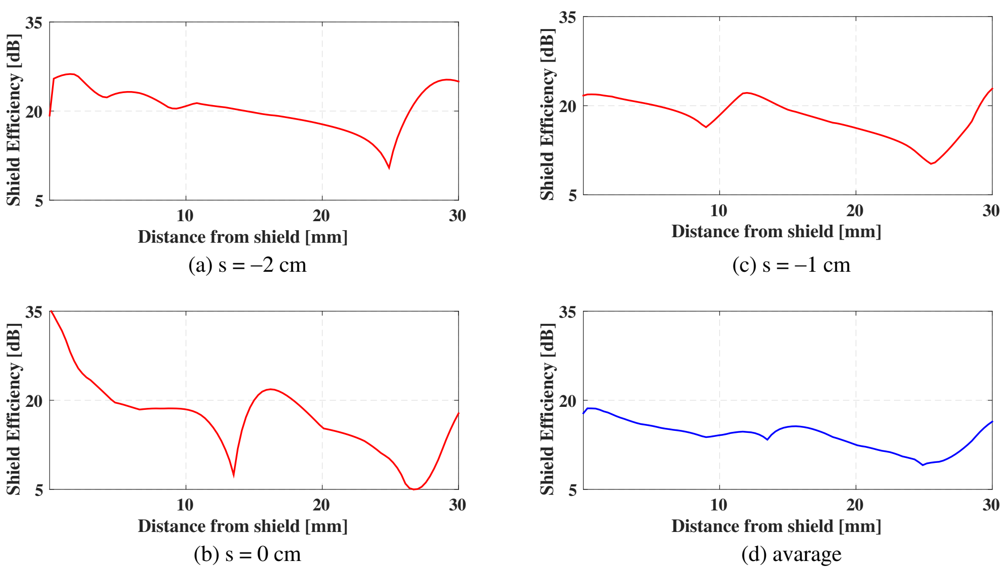


Figure 4: SE evaluated in differents positions of the two shields, (a) is the SE for $s = -2$ mm, (b) is the SE for $s = 0$ mm, (c) is the SE for $s = -1$ mm, (d) is the SE for the avarage values of SE.

As the results show, the buckypapers with a thickness of 5 μm are too thin and they don't produce useful results because the shielding efficiency is too low and too floating, so it's more useful to analyze the cases with greater thicknesses. A thickness of 20 μm provides an higher efficiency in certains points of the screen, but it's a too foating results to be appreciate. Finally, a shield with a tickness of 50 μm provides the best results in terms of shielding efficiency and stability of the results.

4. CONCLUSION

The shielding efficiency is good only when the thickness of the screen is at least 50 μm, below which there are no significant results, but which allow us to have a screen thin enough to be used in medical equipment . Data from experiments encourage us to point out that carbon nanotubes are actually a great material to use as electromagnetic shield and they are rightly identified by the scientific community as the future universal shielding material. All this is absolutely true in electromedical equipment, in which the screen is characterized by a higher sensitivity compared to conventional electronic devices. Therefore the same solutions can be used in terms of shielding electromagnetic interference.

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