On Using the Electrical Characteristics of Graphene-Based Conductors for Designing a Conformal Monopole on a Transparent Substrate

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***Abstract*—Conformal antennas printed on thin flexible substrates typically use copper conductors for the radiating portion of the designs. This paper presents an alternative to using copper conductors. More particularly, a novel compact monopole on a thin transparent substrate with 25 μm thick flexible graphene-based conductors for the radiating portion of the design is presented. The design was modeled in a full-wave simulation tool, and a prototype was manufactured and measured in a full anechoic chamber. Overall, it was shown that the S-parameter simulations agreed well with measurements and that the electrical benefits of the flexible graphene-based conductors could be used to design a useful conformal monopole.**

***Index Terms*—Conformal antenna and flexible graphene-based material.**

I. INTRODUCTION

The development of graphene material has been progressive because of their promising optical, electrical and mechanical properties. Among the many breakthroughs, various forms of graphene have been used to develop transparent material with high dielectric values [1] and improve various properties of composite materials [2]. The objective of this work is to use the electrical properties, and potentially the mechanical benefits, of graphene-based material to develop a conformal monopole antenna. Many of the conformal antennas developed in the past for the aviation industry [3], personal wearable networks [4] and general self-adapting applications [5] have used copper conductors for the radiating portion of the design (i.e., for the microstrip patches and feed networks). However, one drawback of using copper in the design of a conformal antenna is the likelihood of failure due to cracking; and this failure is especially noticeable in the design of the self-adapting arrays reported in [5].

The antenna design presented in this paper is an initial investigation on the electrical benefits of graphene-based conductors [6] to achieve conformal antenna radiation. More specifically, the monopole design shown in Fig. 1(a) is reported. The conducting surfaces such as the reference plane and monopole radiator consists of the flexible graphene-based material as shown in Fig. 1(b) [6], and the substrate is transparency film with a thickness of 0.1 mm.

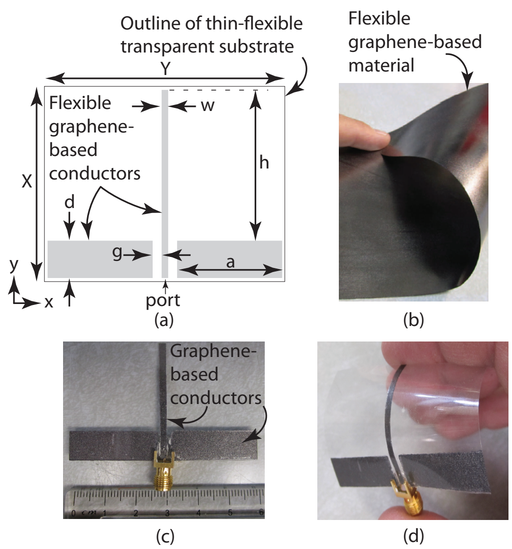

Fig. 1. (a) Drawing of the conformal graphene-based monopole antenna; (b) photograph of the graphene-based material available from [6]; (c) photograph of the manufactured prototype antenna with flexible graphene-based material on a transparent substrate and (d) photograph illustrating the conformal properties of the prototype (a = 27.0 mm, d = 10.0 mm, g = 1.0 mm, h = 30.0 mm, w = 2.0 mm, X = 40.0 mm and Y = 59.0 mm).

II. THE CONFORMAL MONOPOLE WITH GRAPHENE-BASED CONDUCTORS ON A TRANSPARENT SUBSTRATE

To develop the monopole in Fig. 1(a), the conductive properties of the flexible graphene-based material [6] in Fig. 1(b) was required. To experimentally test the conductivity, a known 50Ω microstrip transmission line (TL) with a copper conductor was printed on a known PCB substrate. Then, a microstrip TL that

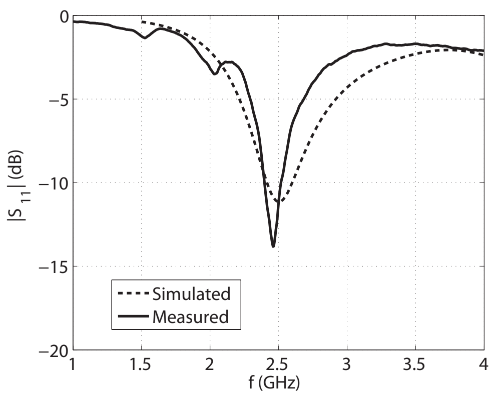

Fig. 2. Measured and simulated $|S_{11}|$ values of the prototype graphene-based antenna.

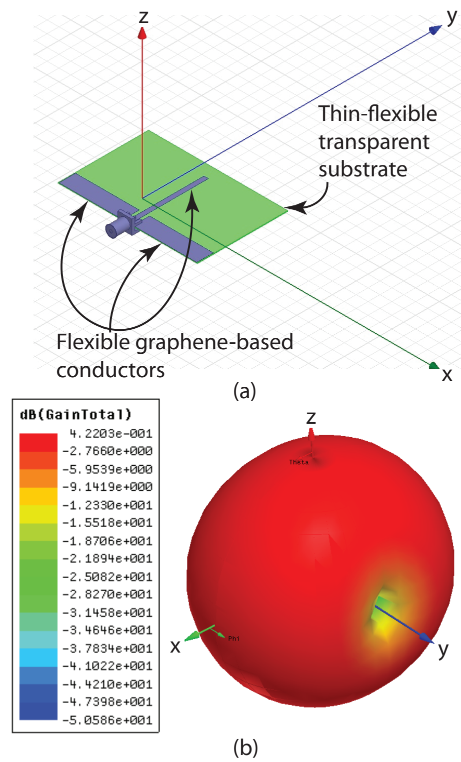

Fig. 3. (a) Model in HFSS and (b) simulated total gain.

used the flexible graphene-based material in Fig. 1(b) instead of the copper conductor was printed on the same substrate as the copper TL with the same dimensions. Then, the simulated (in Momentum [7]) and measured S-parameters of the copper-based and graphene-based TLs were compared from 100 MHz to 4.0 GHz; and overall good agreement was observed for a determined conductivity of $\sigma = 1.94{\times}10^5$ S/m (for a thickness of 25 μm). This information was then used in HFSS [8] to design the monopole in Fig. 1(a) (the dimensions of the monopole are shown in the caption of Fig. 1) on a 0.1 mm thick transparent substrate ($\varepsilon_r \approx 1.0$).

III. Simulation and Measurement Results

The HFSS simulation results of flexible graphene-based monopole are shown in Fig. 2 and an image of the HFSS geometry is shown in Fig. 3(a). With h = 30.0 mm, the resonant frequency was predicted to be $f_o \approx c/4h = 2.5$ GHz, which is close to the simulated result of 2.51 GHz. Next, a prototype of the flexible graphene-based monopole was manufactured. A picture of the prototype with a transparent substrate on a flat surface is shown in Fig. 1(c) and an illustration of the conformal nature of the prototype is shown in Fig. 1(d). Conductive epoxy was used to attach the sma connector. The transparent substrate used for the prototype was inexpensive transparency film (part number: 7-20331) [9]. The $|S_{11}|$ values of the prototype were then measured in a full anechoic chamber and are shown to agree well with simulations in Fig. 2. The measured resonant frequency was 2.46 GHz. Finally, the total gain of the prototype was simulated in HFSS and determined to be 0.42 dB at 2.5 GHz. These values are shown in Fig. 3(b) and a pattern similar to a monopole can be observed.

IV. Conclusion

An initial investigation of a novel conformal monopole consisting of flexible graphene-based conductors on a thin transparent substrate was presented in this paper. The design was simulated in HFSS using extracted material properties, and a prototype was manufactured and tested in a full anechoic chamber. Overall, good agreement between the $|S_{11}|$ values was observed and it was demonstrated that the electrical properties of the graphene-based material were useful for developing a compact conformal monopole antenna. Further research on the mechanical benefits of the flexible graphene-based antenna is planned.

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