Design of a CPW-Fed Graphene-based Conformal Monopole on a Paper Substrate

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***Abstract*—Copper is typically used for the conductor in most antenna designs and flexible materials can be useful to make a conformal antenna. Here, a CPW-fed conformal monopole antenna was designed on a flexible low-cost paper substrate, and flexible graphene-based conductive material was used as an alternative to copper. The antenna was designed for 3.6 GHz applications with a size of 24 mm × 6 mm. The design was simulated in HFSS, a full-wave simulation tool; a prototype was manufactured using a micro-cutter; 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 conductor can be utilized to design a CPW-fed conformal monopole antenna.**

***Index Terms*—Conformal antenna, CPW-fed and flexible graphene-based conductor.**

I. INTRODUCTION

Graphene is gaining more popularity because of its unique electrical, optical, mechanical, and thermal properties. Geim and Novoselov revealed the unique characteristics of graphene in their work [1]. Stankovich and his team worked to develop graphene-based composites and reported this in [2]. Kim and his team used various forms of graphene to develop transparent material with high dielectric values [3]. In the past, many conformal antennas were developed for the aviation industry [4], personal wearable networks [5], and other applications. In those works, copper conductive materials were used for the radiating portion of the design (i.e., for the microstrip patches and feed networks). There has also been research on using graphene-based conductive materials as an alternative of copper. Graphene-based transmission lines [6], and a graphene-based monopole on a transparent substrate [7] was developed earlier which overcame some of the drawbacks of using copper in a conformal antenna. This paper extends the work on transparent substrates and presents a design of a conformal monopole that uses graphene-based conductors on a paper substrate [8] for the first time. More specifically, the monopole design shown in Fig.1(a) is reported here. The conducting surfaces such as the reference plane and monopole radiator consists of the flexible graphene-based material shown in Fig. 1(b) [9], and the substrate is multi-purpose paper with a thickness of 0.1 mm.

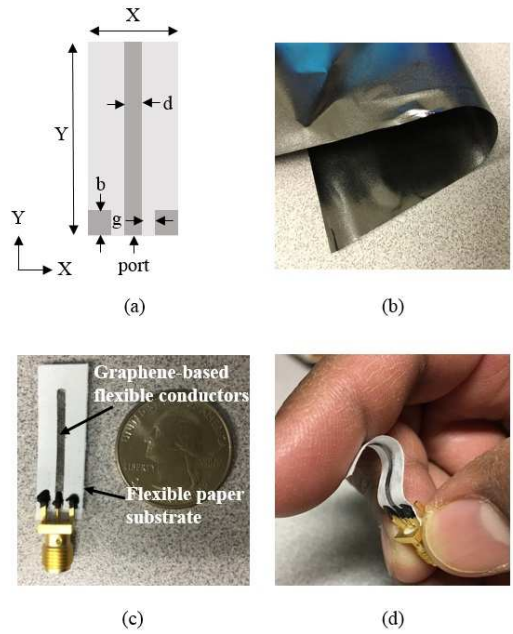


Fig. 1. (a) Dimension of the conformal graphene-based monopole antenna; (b) Photograph of the graphene-based material from [9]; (c) Photograph of the manufactured prototype antenna with flexible graphene-based materials on a paper substrate and (d) Photograph illustrating the conformal properties of the prototype (b = 2.0 mm, d = 1.0 mm, g = 1.0 mm, X = 6.0 mm and Y = 24.0 mm).

II. CPW-FED GRAPHENE-BASED CONFORMAL MONOPOLE ON A PAPER SUBSTRATE

A CPW 50Ω graphene-based microstrip transmission line (TL) was used for the feed network on a 0.1 mm thick paper substrate. A conductivity of σ = 1.94×10^5 S/m [7] (for a thickness of 25 μm) for the graphene-based conductive material was used in the HFSS [10] simulations. The relative permittivity ($\varepsilon_r \approx$ 2.19) and loss tangent ($tan\delta \approx$ 0.035) of the 0.1 mm thick paper substrate were measured with the help of a RF Impedance/Material Analyzer E4991A (1MHz-3GHz) [11]. The graphene-based conductive material was precisely cut using the Cricut Explore Air [12] following the procedure reported in [13].

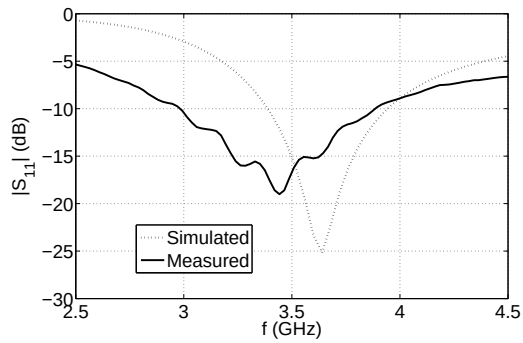


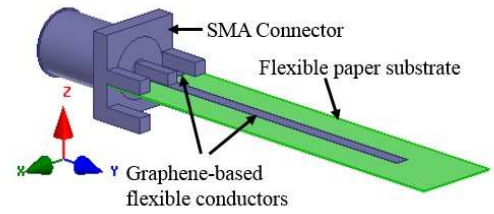
Fig. 2. Measured and simulated $|S_{11}|$ values of graphene-based antenna prototype.

III. RESULTS AND DISCUSSION

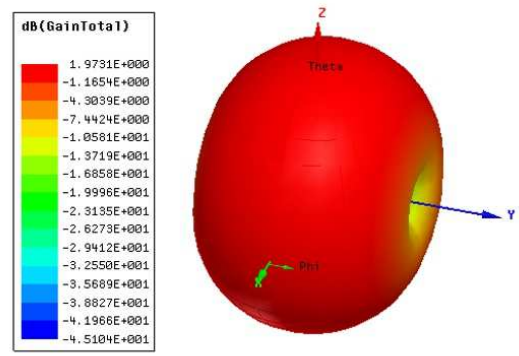
The HFSS simulation results of the CPW-fed graphene-based conformal monopole are shown in Fig. 2 and an image of the HFSS geometry is shown in Fig. 3(a). The resonant frequency was 3.6 GHz, which was designed in simulation. Next, a prototype of the CPW-fed graphene-based monopole on paper was manufactured, and is shown in Fig. 1(c). An illustration of the conformal nature of the prototype is also shown in Fig. 1(d). Conductive glue was used to attach the SMA connector. 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 3.45 GHz, a 4.16 % deviation from simulation results. Finally, the total gain of the prototype was simulated in HFSS and determined to be 1.973 dB at 3.6 GHz. These values are shown in Fig. 3(b) and a pattern similar to a monopole was achieved.

IV. CONCLUSION

A CPW-fed graphene-based monopole antenna was simulated in HFSS using the graphene-based material, and a prototype was manufactured and measured in a full anechoic chamber. Overall, good agreement with small deviations between the $|S_{11}|$ values was observed, and it was shown that a good gain can be achieved using graphene-based conductors and a low-cost paper substrate. It will open up a new avenue for conformal antenna designs on paper substrates, which are affordable in many cases and flexible.



(a)



(b)

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

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