A Microstrip Patch Antenna Manufactured with Flexible Graphene-Based Conducting Material

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***Abstract*—In this paper, a unique process for fabricating microstrip patch antennas with flexible graphene-based conductors is presented. In particular, this manufacturing process uses a commercially available micro-cutter to cut the outline of the patch antenna from the flexible graphene-based conductors, and then this piece is attached to a grounded FR4 substrate using adhesive to create a unique printed antenna. The design was modeled using a commercial simulator, and a prototype was fabricated and measured. Overall, it was shown that the S-parameter simulations agreed fairly well with measurements, and that this manufacturing process has the potential to develop more complicated designs, such as meander-line dipoles for example, that are difficult to cut-out manually.**

***Index Terms*—Patch antenna and graphene-based conductors.**

I. INTRODUCTION

Modern wireless communication systems are being required to operate in evermore complicated environments. This is because these systems are being applied to problems that (1) involve surfaces that change shape with time, (2) include wearable networks and/or (3) are subjected extreme environmental temperature/pressure changes [1]. Because of the wireless nature of these systems, the antenna is a major part of the design and conformal antennas have the potential to overcome some of the aforementioned difficulties. However, one drawback of using a traditional conformal antenna can be the copper conductors. This is because of the weight and the potential for copper failure due to repetitive bending deformations, which was noticed in the work reported in [1]. To mitigate some of these issues, a flexible graphene-based conducting material [2] is being explored as a possibility of replacing the etched copper in a conformal antenna. A picture of the material is shown in Fig. 1(a). However, an efficient manufacturing process for fabricating complicated antenna designs based on this material is required. Thus, the objective of this paper is to present a suitable manufacturing process and introduce the graphene-based microstrip patch antenna shown in Fig. 1(b). This provided a standard design that has been well understood and was marginally complicated.

An initial investigation on graphene patch antennas at microwave frequencies was reported in [3] and later discussed in [4]. The authors of these papers summarized the benefits of graphene as a mono-atomic structure, whereas the presented work builds on these ideas and explores the potentials of using graphene-based conductors that are commercially available and much thicker than a single layer for printed antenna purposes.

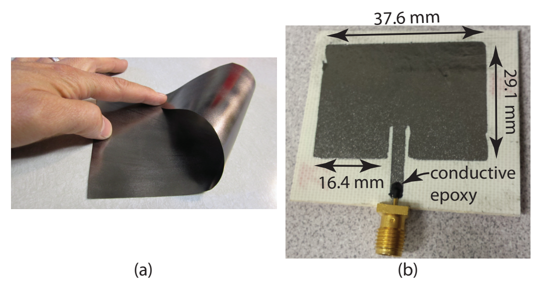

Fig. 1. Photograph of the commercially available flexible graphene-based conducting material and (b) a photograph of the prototype (with dimensions) of the fabricated graphene-based patch antenna.

II. THE MANUFACTURING PROCESS

Several steps are required to prepare the graphene-based conductor material in Fig. 1(a) for manufacturing. Initially, the temporary spray adhesive (Sulky KK 2000 [6]) shown in Fig. 3 is applied to the top surface of a 100 μm thick sheet of paper and bonded to the bottom surface of the graphene-based conducting material (Fig. 2). Next, the same spray adhesive is applied to the bottom surface of a 100 μm thick transparency film and bonded to the top surface of the graphene-based conducting material (also shown in Fig. 2). As a result, the three layers are bonded together for manufacturing, giving the 3-layer structure shown in Fig. 2. The 3-layer structure is then placed on the adhesive cutting mat shown in Fig. 3. The graphene-based conducting layer is now ready for cutting out the shape of the microstrip patch. It should be noted that the three layers were pressed together by hand and the temporary adhesive was cured at room temperature for 2 - 3 minutes before cutting. This allowed for the separation of the three layer after the cutting process was completed. Finally, the layout of the patch is defined in the software included with the micro-cutter, which is discussed in the next section.

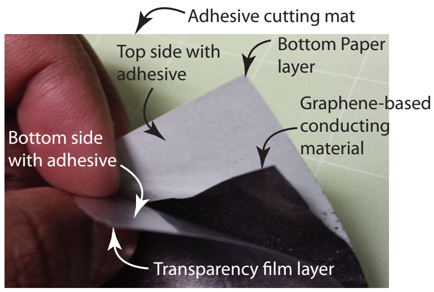

Fig. 2. Photograph of the flexible graphene-based conductors placed in between different layers to fabricate the antenna.

Fig. 3. Photograph of the commercial micro-cutter [5] and the temporary adhesive spray [6].

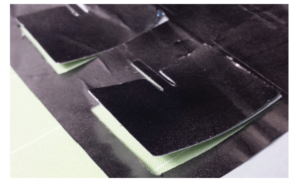

Fig. 4. Fabrication step to separate the flexible graphene-based conducting layer of the patch from the protected layers.

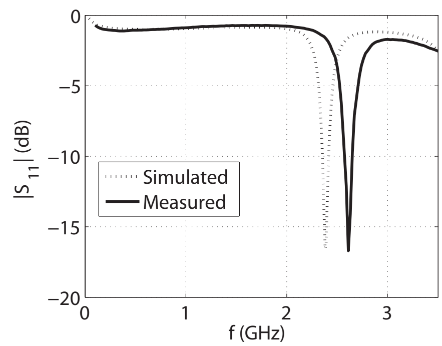

Fig. 5. Measured and simulated $|S_{11}|$ values of the prototype graphene-based antenna.

III. Design and Evaluation of the Prototype Microstrip Patch Antenna

To develop the patch antenna in Fig. 1, the conductive properties of the graphene-based material [2] were determined by measuring the S-parameters of a known printed microstrip transmission line that used the graphene-based conductors instead of copper. The conductivity was determined to be σ = 1.94×10^5 S/m for a thickness of 25 μm. Next, this thickness and conductivity were used in the commercial simulation software ADS [7] to determine the geometry of the patch antenna shown in Fig. 1(b). The simulated S-parameters are shown in Fig. 5. The resonant frequency was predicted to be 2.4 GHz and the grounded FR4 substrate was 1.5 mm thick with ε_r = 4.5 (the bottom layer of the FR4 was 0.5 oz copper). Then, this geometry was drawn in the software included with the micro-cutter and used to cut out the graphene-based conducting layers shown in Fig. 4. As a final step, the graphene-based conducting patch was removed from the 3-layer structure and attached to the FR4 substrate. The result was the prototype shown in Fig. 1(b). The center conductor of the SMA connector was attached to the patch with conductive epoxy. Next, the $|S_{11}|$ values of the prototype were measured in an anechoic chamber and are shown in Fig. 5. The resonant frequency was 2.6 GHz.

Several comments can be made about the results in Figs. 1(b) and 5. Closer observation of the edges in Fig. 1(b) shows that the micro-cutter blade tends to wobble slightly during cutting, which may be the cause of the differences in the S-parameters in Fig. 5. This behaviour could be due to the blade depth setting and further exploration is planned in the near future. On the other hand, the results in Fig. 5 show that a new patch antenna can be developed using this flexible graphene-based material, which may be difficult to otherwise manufacture with the existing PCB techniques.

IV. Conclusion

An initial investigation of a new patch antenna that uses flexible graphene-based conductive material was introduced in this paper. Additionally, a unique process of manufacturing these patch antennas with the graphene-based material was presented. The design was simulated in ADS using extracted material properties, and a prototype was fabricated and tested. Overall, fair agreement between the $|S_{11}|$ values was observed and it was demonstrated that moderately complex geometries could be manufactured using a simple and cost-efficient commercially available micro-cutter.

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