A Conformal Antenna on a Passive UHF RFID tag using 97% Carbon Content Graphene-Based Conductors and Paper Substrates

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***Abstract*—Passive UHF radio frequency identification (RFID) systems are being applied to many different industries and because of this, these systems are being required to operate in complex electromagnetic environments. This may require tags to operate on different surface types or time varying shapes. This paper presents a conformal antenna design that can be used on a passive UHF RFID tag with a paper substrate. More specifically, instead of copper conductors for the antenna, commercially available 97% carbon content graphene-based material is used to mitigate conductor failure; which has been observed in copper-based conformal antenna designs. Simulations and read-range measurements (2.1 meters) of a prototype UHF passive RFID tag with graphene-based conductors and dimensions similar to commercially available copper-based designs are shown.**

I. Introduction

A passive radio frequency identification (RFID) tag typically consists of three major components, namely an IC, antenna and substrate [1]. Of these, there has been extensive research conducted on different ICs [1], antenna layouts (i.e., compact designs) for different applications [2] and different thin substrates for attachment to various conformal surfaces [3]. However, in much of the earlier work reported on RFID antenna designs, the material used was copper. It is well known that copper is a good conductor; however, the properties of this material can be altered if it is attached to a conformal surface that changes shape with time [4]. The objective of this paper is to present the new design shown in Fig. 1 that uses graphene-based conductors [5] instead of copper as a method to develop a conformal antenna on a passive UHF RFID tag with a paper substrate. A graphene-based conductor has been shown to be less vulnerable to surface changes and is a material that can be used in UHF antenna designs on conformal surfaces [5].

II. Development of The Graphene-based Conductor Antenna

The layout of the proposed antenna is shown in Fig. 1(a). A meander-line design was chosen to reduce the overall size of the antenna [2] and hence the tag. Then, instead of using copper, the commercially available 97% carbon content graphene-based material (by Graphene Supermarket Part number: GRAPH-SHEET-8x8-10 [6]) shown in Fig. 1(b) was used as a conductor.

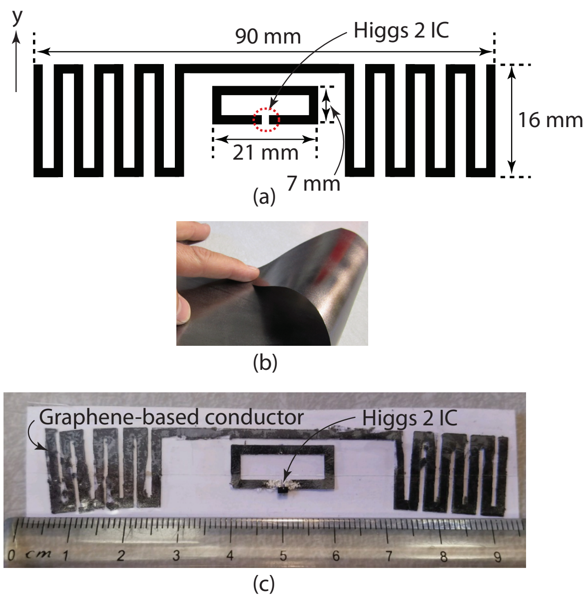

Fig. 1. (a) Topology and dimensions of the antenna on the UHF RFID tag; (b) photograph of the commercially available 97% carbon content graphene-based material used for the antenna and (c) photograph of the prototype UHF RFID tag with graphene-based conductors and a paper substrate.

A. Simulations of the Graphene-based Antenna

Initially, the antenna was modeled in HFSS [7] on a 0.1 mm thick paper substrate with ε_r = 2.19 and $\tan\delta$ = 0.035. The dielectric properties of the paper substrate were measured using a RF Impedance/Material Analyzer E4991A (1MHz-3GHz) [8]. According to the data sheet, the thickness of the graphene-based layer was 25 μm and had a sheet resistance of 2.8×10^{-2} Ω/square [6]. For the prototype, an Alien Higgs 2 IC [9] was chosen for demonstration purposes only. At 915 MHz,

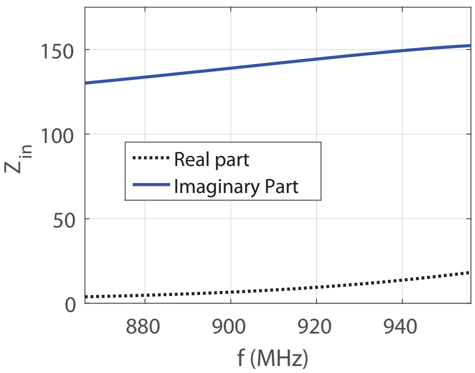

Fig. 2. Simulated input impedance of the antenna with graphene-based conductors.

the input impedance of the IC was 13.8-j143.6 Ω. With the dimensions shown in Fig. 1(a), the input impedance computed in HFSS was 8.61+j143 at 915 MHz. The real and imaginary parts of the simulated values are shown in Fig. 2. It should also be noted that a pattern similar to a dipole was observed.

B. Measurements of the Prototype

Next, a prototype of a passive RFID tag with the design in Fig. 1(a) was manufactured. This was done using the procedure reported in [10]. In summary, the antenna manufacturing technique consisted of a three-layer structure. The bottom layer was 0.1 mm thick paper, the middle layer was the graphene-based material shown in Fig. 1(b) and the top layer was transparency film. The graphene material was lightly adhered to the paper layer and the transparency film was used to hold down the graphene-based material during cutting. Then, a micro-cutter [11] was used to cut-out the shape of the antenna. The cutter went through all three layers. Then, the paper and transparent layers were removed by hand and the graphene-based material in the shape of the antenna remained. This antenna was then attached to the paper substrate to form the prototype passive tag shown in Fig. 1(c). The Higgs 2 IC was attached to the port using conductive silver epoxy.

Then, the read range of the prototype was measured in a full anechoic chamber. An Alien 9780 reader [9] (with a maximum output power of 1 W) connected to a CP antenna with a gain of 6 dBi was used for these measurements as shown in Fig. 3(a). The prototype tag was attached to a styrofoam block and is shown in the chamber in Fig. 3(b). The read-range was found by moving the tag away from the reader antenna until reading ended. It was shown that a read-range of 2.1 m could be achieved and verified the simulation results in Fig. 2.

III. Conclusion

An antenna design that uses commercially available 97% carbon content graphene-based conductors instead of copper for passive UHF radio frequency identification (RFID) tags has been presented in this paper. It has been demonstrated that the conducting properties and additional benefit of conformality of graphene-based conductors could be be used to develop a passive UHF RFID tag. Measurements show that useful read-ranges of 2.1 could be achieved for tags on thin conformal paper substrates.

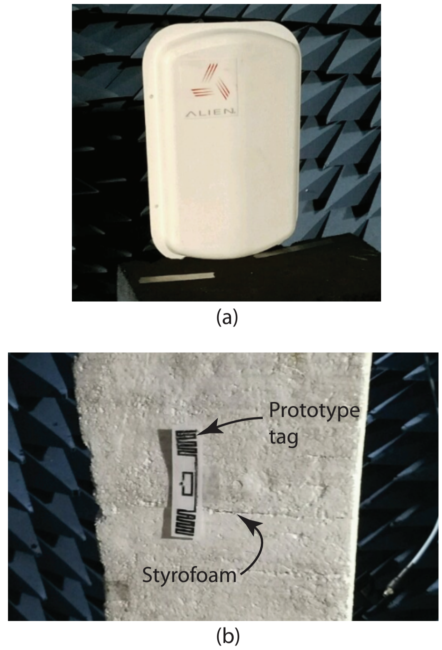

Fig. 3. (a) Photograph of the antenna on the RFID reader in the full anechoic chamber during read-range measurements and (b) photograph of the read-range of the prototype tag being measured in the full anechoic chamber.

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