A Properties Comparison Between Copper and Graphene-based UWB MIMO Planar Antennas

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***Abstract*—This paper presents the comparison of two Ultra-wideband (UWB) Multiple-Input-Multiple-Output (MIMO) antennas with different conductors. In the simulation two UWB-MIMO antennas with copper conductors and graphene-based conductors (GBC) are designed separately. The ground planes of both radiators are made of copper, only the top side is made with different conductors. A T-shaped decoupling structure is placed on the ground plane to reduce the coupling between the radiating patches. These two prototypes, one with copper conductors and the other one with GBCs are fabricated. A good agreement between the S-parameters of both prototypes is found. The measured radiation patterns of both prototypes also exhibit similar properties. Whereas, the GBC antenna showed a lower gain as compared to the copper antenna, as depicted in radiation patterns. However, impedance matching and the radiation characteristics of the GBC antenna also showed that graphene can be a good alternative to copper in UWB-MIMO conformal antennas.**

I. INTRODUCTION

Due to inherent features like wide bandwidth, low cost and high data transmission, Ultra-wideband (UWB) has been widely used in wireless communication systems in recent years. On the other hand, the multipath fading degrades the performance of UWB technologies. To overcome this problem, multiple-input multiple-output (MIMO) systems have been combined with the UWB technologies. These systems require low mutual coupling (less than -15 dB) among their elements.

Various methods have been applied on UWB-MIMO antennas to reduce the coupling among their elements while preserving the compactness of the antenna [1]-[4]. In [1], five floating parasitic elements, while in [2], a structured ground plane (decoupling structure), was used to reduce the coupling over a wide band. Slots were used in the antenna to achieve the pattern diversity [3]. In [4], polarization diversity between two orthogonally placed antenna elements was exploited to reduce the coupling. All the previous work used the copper conductor. The copper has a good conductivity but it is not resistant to cracking because of the hard mechanical strengths. Recently, other conducting materials such as GBCs [5], having good mechanical strengths, have been used as an alternative to copper in the antenna design as reported in [6], [7].

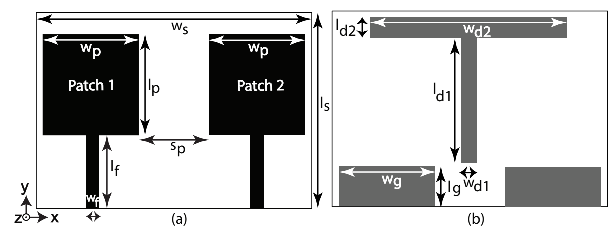

Fig. 1. Layout of the proposed antenna. (a) Top side, and (b) bottom side. Optimized dimensions in mm are: $w_s = 37.5,\ l_s = 28,\ w_p = 12,\ l_p = 13.2,\ w_f = 1.5,\ l_f = 10.5,\ s_p = 11.5,\ w_g = 12.5,\ l_g = 5.8,\ w_{d1} = 2.0,\ w_{d2} = 17,\ l_{d1} = 17,\ l_{d2} = 3.$

This paper is an extension of the work reported in [6] and explores the use of GBCs in the design of an UWB MIMO antenna. Furthermore, a comparison of the GBC UWB-MIMO antenna with a copper UWB-MIMO antenna with the same dimensions is presented. For both the prototypes, copper was used on the bottom sides of the radiators. The simulation and measurement results showed that the impedance matching and radiation properties of both the designs are similar.

II. ANTENNA DESIGN

The proposed antenna geometry along with its dimensions is shown in Fig. 1. Initially a rectangular patch UWB antenna with a partial ground plane was designed. Next, a second radiator was placed at a distance of ($s_p = 11.5\ mm$) from the edge of the first conductor. A strong coupling was observed between the two radiators. To reduce the coupling, a T-shaped decoupling structure was placed on the back side of the radiators. To check the performance of the antenna with the GBC, a 25 μm thick GBC sheet, conductivity $(\sigma) = 1.94 \times 10^{54}\ S/m$ was used in the simulations, as determined in [6]. In the simulations, a good agreement between the S-parameters of copper and GBC conductors was found.

III. EXPERIMENTAL VALIDATION

Then, both prototypes were fabricated on a 1.524 mm thick Rogers TMM4 laminate ($\epsilon_r = 4.5,\ tan\delta = 0.002$), as shown in Fig. 2. The prototype with copper was fabricated using

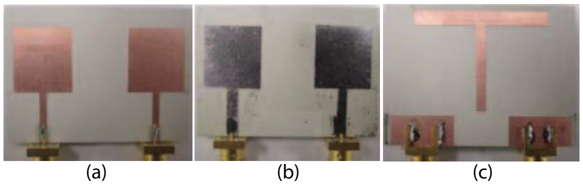

Fig. 2. Fabricated prototypes. (a) Top side with copper (b) top side with GBC, and (c) bottom side.

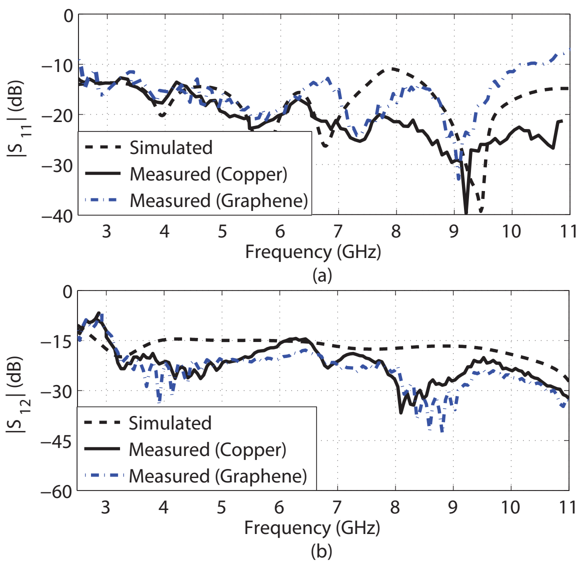

Fig. 3. Simulated and measured s-parameters. (a) $|S_{11}|$ and (b) $|S_{12}|$.

the LPKF milling machine but for the GBC antenna, the optimized antenna design shape was first manually cut out from a GBC sheet. This sheet was then guided in place on to the TMM4 substrate and glued using a spray adhesive. A straight edge RF SMA connector was then positioned on the GBC feed line and soldered to the partial ground plane (1/2 oz copper). The feed line was finally connected with the SMA connector using the conductive epoxy. The measurements were then taken in an anechoic chamber using an Agilent N5230A PNA-L network analyzer. Overall, a good agreement between simulated and measured S-parameters was observed from 3 to 11 GHz, as shown in Fig. 3. The small discrepancy between simulated and measured results was thought to be due to the fabrication tolerance. The discrepancy between the copper and GBC conductor is due to manual fabrication of GBC conductor antenna.

The measured radiation patterns of both the xz and yz-planes are plotted in Fig. 4. It can be seen that the patterns of the copper based conductor are almost identical to the GBC. The gain of the GBC antenna is lower than the copper based conductor because copper is highly conductive material with respect to graphene. Looking at the Figs. 4 (a) and (b), it can be seen that the gain is reaching almost 7 dB at 10 GHz for the copper conductor antenna, while the gain for the GBC antenna

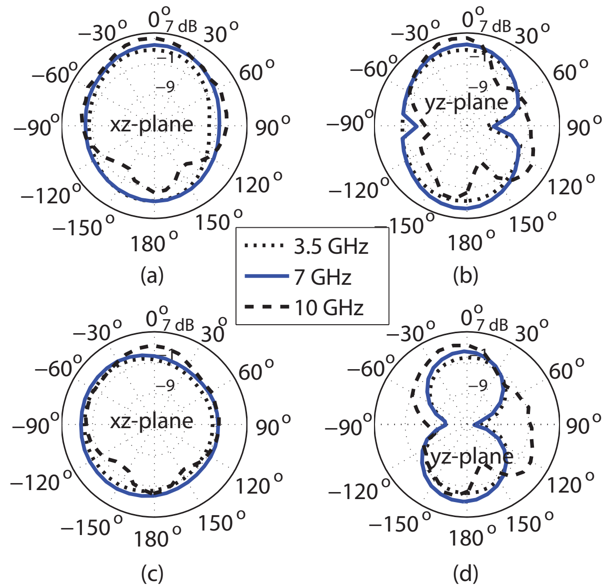

Fig. 4. Measured gain patterns at 3.5, 7 and 10 GHz. (a) xz-plane of copper antenna (b) yz-plane of copper antenna (c) xz-plane of GBC antenna, and (d) yz-plane of GBC antenna.

at 10 GHz is 5.6 dBi, as depicted in Figs. 4 (c) and (d).

IV. Conclusion

A comparison of two UWB-MIMO antennas is presented. The top side of one antenna was made with copper while the other one was made with a GBC. The ground plane of both prototypes was made with the copper. A T-shaped decoupling structure was used on the bottom side of the antennas to reduce the mutual coupling between antenna elements. A good agreement between S-parameters and the radiation patterns of both prototype was observed. The gain of the GBC antenna was lower than the copper based antenna. Having almost similar features, it was shown here that GBCs can be a good alternative to copper on conformal surfaces.

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