~~Graphene Based~~ Textile Antennas for Integrated and Wearable Applications

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***Abstract*—This paper presents ~~an antenna designed to achieve wideband by~~ using graphene as a conductive patch. In order to provide flexibility, the cotton fabric is used as a substrate. The proposed antenna covers a bandwidth of 2–8 GHz. Simulated antenna efficiency is approximately 60% in overall bandwidth. The attractive features of conformity, lower design complexity and fabrication ease as well as integration of an environment friendly and low cost graphene have suggested the proposed antenna well-suited for body-centric, biomedical and wearable applications.**

Keywords—antenna; graphene; textile; wearable; wireless.

I. Introduction

Wireless technology has experienced notable advancement in the past decade in mobile communication networks and user-friendly applications [1]. The ever-growing number of wireless devices and especially body-centric gadgets has motivated the research to focus on the utilization of new materials. Among the choices of recent materials, graphene is extensively highlighted due to its unique features and eco-friendly nature [2]. Graphene is a two-dimensional carbon crystal with remarkable electrical conductivity to allow propagation of high-frequency signals [3]. In wireless devices, antenna is regarded as a core module and in order to realise graphene based radio-frequency (RF) circuitries, intensive efforts have been made in the design, implementation and performance evaluation of the graphene antennas [4-6].

Patch antennas have the advantage of planar integrations, however, for the wearable and body-centric applications, the conformity of the antenna is highly desirable, which can only be realized by flexible substrate. Textile based antennas are capable to provide an ease of integration in wearable electronics. Several methods of fabrication, such as, inkjet printing, screen printing, conductive embroidering, or by adhesive conductive fabric patterning, are developed for the implementation of textile antennas [7]. The research suggests a graphene based antenna on a textile substrate as a potential candidate for smart textiles and state-of-the-art body-centric systems.

II. Antenna Design and Fabrication

A. Antenna Design and Numerical Modelling

The designed antenna consists of a coplanar-waveguide (CPW)-fed planar inverted cone shaped patch geometry [9], where the optimised dimensions (in mm) are as shown in Fig. 1 (a). Two layers of different substrates are used, i.e. thin sheet of micro-glass fiber and a cotton textile. The graphene patch is designed on a micro glass-fiber (thickness = 1.5 mm, dielectric constant = 5) which is backed with a cotton fabric to provide additional support, lowers the value of effective permittivity and increases the thickness and robustness of the prototype.

B. Synthesis of Multilayer Graphene and Transfer Printing of Graphene on Polyethylene Sheets

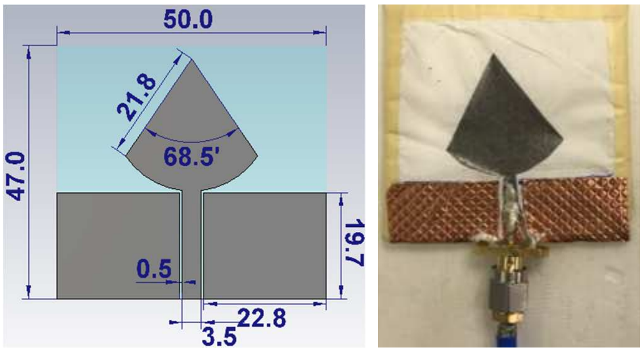
Multilayer graphene samples were synthesized on 50 μm thick nickel foils using chemical vapor deposition system. The thickness of ML graphene samples were controlled by the growth temperatures varied between 900–1000 °C. The number of graphene layers was approx. 100. Transfer printing of large area ML-graphene on a 20 μm thick porous polyethylene (PE) substrate was conducted. Porous PE sheet was immersed into liquid for conformal coating of ML graphene, and then dried in an oven at 70 °C for 2 hours to remove residual water molecules. The sheet resistance of ML-graphene was *c.a* 25 Ω/sq.

C. Fabrication of Graphene Based Textile Antenna

The ML-graphene sheets were laminated with insulating glass microfibers nonwoven supplied from Pilkington *Co.* to avoid possible short-circuiting effect of crinkled graphene edges touching fabric. The graphene sheet was cut and transferred onto micro glass-fiber by heat lamination as in Fig. 1 (b). This method triggered by applied heat assists bonding between the two sheets provides strong interface. Adhesive copper tape was placed on top for CPW ground. The structure is then backed with a fabric.

III. Performance Evaluation of the Antenna

The antenna performance is evaluated by parametric analysis and investigation of results of S-parameters, radiation pattern, realized gain and efficiency. The results obtained in numerical estimation and testing of the fabricated prototype shows a good agreement. Though some mismatches are observed due to fabrication tolerances or real-time losses during testing which have not be accommodated in simulation. Fig. 2 shows that the simulation cover complete 2–8 GHz band, while the measurements taken from the Vector Network Analyser (VNA) illustrate a bandwidth of 2.45–8 GHz.



(a) (b)

Fig. 1. The proposed graphene based antenna (a) simulated model with optimised dimensions in mm; (b) fabricated model.

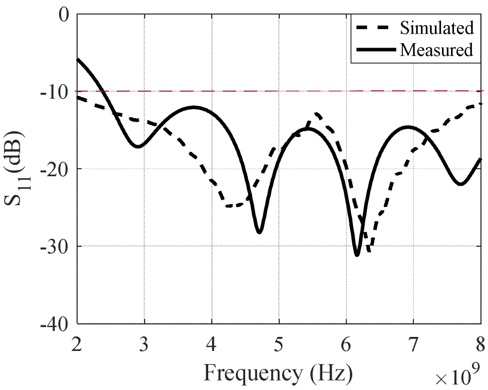
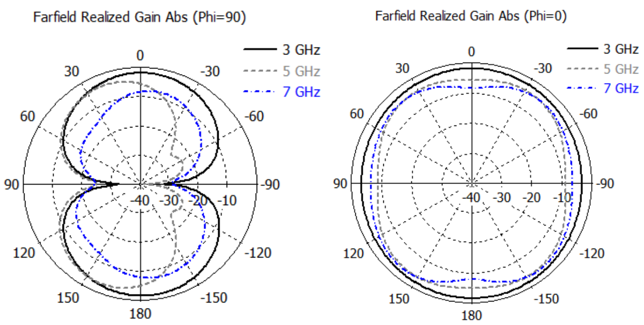


Fig. 2. Simulated and measured S_{11} of the proposed graphene based antenna.

The radiation patterns of the antenna are shown in Fig. 3 for both E and H-plane cuts. The magnitudes are normalized with the value of peak gain of 2.83 dBi. The plots shows a fairly consistent omnidirectional radiation pattern. Fig. 4 shows the simulated efficiency vs. frequency of the proposed antenna. The total efficiency of the designed antenna computed in CST simulation is ~60% in the desired range of operation, which is significantly good for textile based antennas.



(a) (b)

Fig. 3. The radiation pattern of the proposed graphene based antenna.; (a) E-plane cut, at φ = 90˚, (b) H-plane cut, at φ = 0˚.

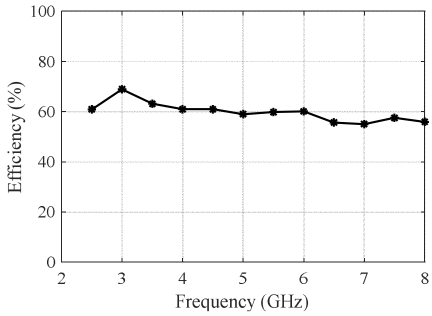


Fig. 4. Simulated antenna efficiency of the proposed graphene based antenna.

IV. Conclusion

This paper has presented a graphene based antenna which is designed and implemented on a flexible textile substrate to achieve desired level of conformity. The antenna has attained an impedance bandwidth of 6 GHz ranging from 2–8 GHz. The omnidirectional radiation has been observed due to co-planar structure. The simulated results has shown that the realized gain of the antenna ~3 dBi with the antenna efficiency of ~60 %. The designed antenna has potential in advanced materials devices, especially in the conformal biomedical applications.

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References

[1] S. F. Jilani, A. K. Aziz, Q. H. Abbasi and A. Alomainy, "Ka-band flexible koch fractal antenna with defected ground structure for 5G wearable and conformal applications," *IEEE 29th Annual Int. Symp. Personal, Indoor and Mobile Radio Communications (PIMRC)*, 2018, pp. 361–364.

[2] T. Palacios, A. Hsu, and H. Wang, "Applications of graphene devices in RF communications," *IEEE Commun. Mag*., vol. 48, no. 6, pp. 122–128, Jun. 2010.

[3] A. C. Ferrari et al., "Science and technology roadmap for graphene, related two-dimensional crystals, and hybrid systems," Nanoscale, vol. 7, no. 11, pp. 4598–4810, 2015.

[4] L. Zakrajsek, E. Einarsson, N. Thawdar, M. Medley and J. M. Jornet, "Lithographically defined plasmonic graphene antennas for terahertz-band communication," *IEEE Antennas Wireless Propag. Lett*., vol. 15, pp. 1553–1556, 2016.

[5] M. Akbari, M. W. A. Khan, M. Hasani, T. Björninen, L. Sydänheimo and L. Ukkonen, "Fabrication and characterization of graphene antenna for low-cost and environmentally friendly RFID tags," *IEEE Antennas Wireless Propag. Lett*., vol. 15, pp. 1569–1572, 2016.

[6] J. Li, M. He, C. Wu and C. Zhang, "Radiation-pattern-reconfigurable graphene leaky-wave antenna at terahertz band based on dielectric grating structure," *IEEE Antennas Wireless Propag. Lett*., vol. 16, pp. 1771–1775, 2017.

[7] A. da Conceição Andrade, I. P. Fonseca, S. F. Jilani and A. Alomainy, "Reconfigurable textile-based ultra-wideband antenna for wearable applications," 10th European Conference on Antennas and Propagation (EuCAP), 2016, pp. 1–4.

[8] A. Alomainy, A. Sani, A. Rahman, J. Santas and Y. Hao, "Transient characteristics of wearable antennas and radio propagation channels for ultra wideband body–centric wireless communications," *IEEE Trans. Antennas Propag., Special Issue on Body–Centric Wireless Networks*, vol. 57, no. 4, Part 1, pp. 875–884, 2009.