CHALLENGES AND FUTURE DIRECTION OF CHIPLESS RFID SENSOR ANTENNAS IN STRAIN SENSING APPROACH

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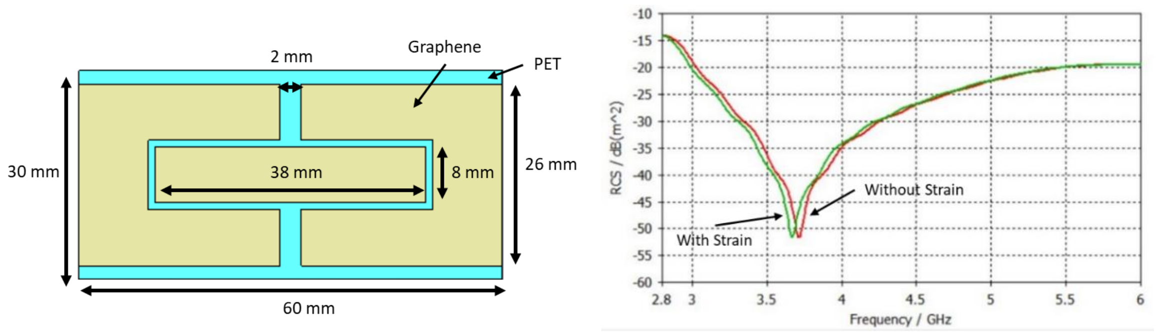
Metal structures in power plants, mining, aircraft etc. are vulnerable to excessive cyclic loading which is the main cause of strain. Strain sensing is essential for early damage detection in such metallic structures to address problems before they become severe, reducing the need for extensive and costly repairs. The conventional strain sensors, in this regard, suffer from complex wired system, and need costly supporting equipment for maintenance. Therefore, wireless sensing in structural health monitoring (SHM) is a great pathway to detect strain with reduced cost and complexity. Chipless radio frequency identification (RFID) technology provides wireless and smart sensing approach using electromagnetic signature [1], and has the potential for monitoring reliable and efficient information about strain during structure deformation. The resonance frequency of the sensor antenna shifts due to slight variation in the antenna length during the applied strain. This high sensitivity, in addition to the competence of noncontact measurement of the sensor at the tag side, makes this technology an interesting candidate for strain sensing in SHM applications.

Different sensing materials and the RFID sensor patterns investigated for strain detection in literatures. Microstrip patch structures have been fabricated with copper as a sensing material in several studies [2-3], and used as RFID strain sensors for getting higher sensitivity. But, the high Young modulus of copper makes it less sensitive during mechanical deformation. Therefore, flexible metallic materials such as silver ink has been proposed to make RFID strain sensors suitable for stretchable and complex structural applications [4]. Along with these metallic materials, carbon-type materials such as graphene is making its footmark in strain sensing approach due to large surface area and high elastic stiffness [5]. But, the challenge to replace graphene as a sensing material instead of metallic materials is its resistivity which is much higher. Besides with sensing materials, digging up the efficient antenna patterns is also important to achieve reliable strain sensing information as well as higher sensitivity.

Fig. 1(a) shows the structure of proposed chipless RFID strain sensor antenna. Here, we use graphene as a sensing material with a thickness of 0.026 mm and electrical conductivity of $1.6 \times 10^6 Sm^{-1}$. The graphene was affixed to the PET flexible substrate, the substrate thickness is 0.05 mm, the dielectric constant is 3.9, and the tangential loss is 0.003. Fig. 1(b) shows the simulated RCS curves for the antenna with and without applied strain. The resonance frequency of the sensor antenna is 3.72 GHz without strain, and for horizontally applied strain, the length has been increased by 1 mm and the resonance frequency decreases to 3.67 GHz. So, the change of resonance frequency for stretching 1 mm is 50 kHz (i.e., sensitivity). Besides, the radar cross section (RCS) value for both cases are around -52 dBm^2. But, along with these sensitivity and improved RCS, the high quality (Q) factor is also important for reliable and precise sensing. Therefore, the challenge is to excavate efficient graphene-based antenna pattern for achieving higher Q factor that need to be addressed in future chipless RFID strain sensing approach.



(a) (b)

Fig. 1: (a) Structure of graphene based chipless RFID strain sensor antenna, (b) Simulated RCS for applied strain.

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