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Investigation of multi-functional metamaterial unit cell operating at SHX-X Band frequencies

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Metamaterials are man-made materials having unique and distinct properties which are not available in natural materials. In this study, a metamaterial unit cell is fabricated with a square-circular-hexagonal split ring resonator. The feasibility of the fabricated unit cell as a perfect absorber, sensor, and antenna is investigated. The proposed unit cell structure is initially simulated, numerically analysed, and optimized using High Frequency Structure Simulator (HFSS), a commercially available EM simulation software. First, the potential of the designed unit cell to be functioned as highly efficient metamaterial absorber in the Super High Frequency (SHF) – X band is verified. Simulations revealed that the reflection coefficient S11 is lower than 10 dB across the whole test frequency range around 9.2 GHz and the absorptivity is 99.8%. Unit cell has been fabricated with standard PCB fabrication process. The fabricated unit cell is composed of alternate layers of Cu and FR4 dielectric medium in which a Cu split ring absorbs all incident electric and magnetic fields within a single planar layer that is only 0.6 mm thick. Experimental characteristics of the designed unit cell were analysed using the Vector Network Analyzer (VNA). To observe the resonant behaviour a non-contact measurement was performed with home-made copper ring due to the increased accuracy. Experimental results showed relatively high Q-factor revealing that the designed unit cell has lower energy dissipation as compared to the energy stored. By replacing the FR4 layer in the metamaterial absorber (MMA) unit cell with a sensor layer made of air, a design for a metamaterial sensor is suggested liquid density sensing applications. The liquids with different densities were inserted to the air layer and the respective resonance frequencies were obtained. A change in the resonant frequency shifting of the metamaterial unit cell show that it can be used as a liquid density sensor. The proposed sensor can be employed in microwave frequency range for chemical, biological, agricultural, and medical applications. Finally, a design for a metamaterial patch antenna is proposed using the same unit cell. It is made of three layers consisting of the patch and the ground layer made of Cu and the substrate with FR4 dielectric material in between. The patch antenna was found to resonate at several frequencies between 0 and 15 GHz, with the lowest S11 reflection coefficient measured at 7.52 GHz and -21.2456 dB. We envision that this antenna will find application in the miniaturization and integration of various telecommunication equipment functions, particularly for items that are used frequently in daily life such as mobile communication systems, smart phones, portable tablets, GPS receivers, wireless Internet devices, etc.

Keywords: Electromagnetic energy, Metamaterial microstrip patch antenna, Metamaterial sensor, Perfect metamaterial absorber, Wireless energy harnessing

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