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Design and Characterisation of an Uncooled Monopole Antenna for Microwave Ablation

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Microwave ablation is a minimally invasive method that can be used to treat several medical conditions. Such a methodology is commonly used to treat tumours. Microwave ablation provides a minimally invasive alternative to open surgical therapies, potentially reducing morbidity and postoperative complications. This percutaneous treatment is performed with a needle-like applicator guided inside the target tissue. The applicator incorporates a microwave antenna. When energised, the interaction of the microwave electric fields with the surrounding tissue causes localised heating (>100 ℃), thus destroying the targeted tumour cells. Clinically available systems operate at 915 MHz and 2.45 GHz, where forced cooled applicators by means of chilled saline water or CO_2 are typically used. Cooling the applicator is known to reduce the tailing effect and produces a more ellipsoidal lobe compared to the teardrop shape of an uncooled antenna, with the disadvantage of added complexity and cost of the ablation system [1, 2, 3].

During this study, an uncooled coaxial-based monopole antenna at 2.45 GHz was investigated both electrically and thermally. The designed antenna was used to investigate the impact of power and time on the lesion created, and a corresponding numerical model was developed in CST Microwave Studio.

A microwave ablation system was assembled in the laboratory and thoroughly characterised to perform repeatable ablation experiments in ex-vivo porcine specimens. The characterisation of the system was achieved by conducting a set of experiments, emulating the antenna by a matched load. An uncooled coaxial-based monopole antenna was also designed and optimally tuned to achieve the lowest reflection coefficient when immersed in the porcine liver. The antenna was primarily developed in simulation software, where the model was pre-validated with experiments utilising liver, blood and muscle mimicking solutions and applying transmission line techniques to measure and compare impedances. The antenna was constructed using minced liver (homogenised liver), and the comparison of results with those achieved through simulation showed congruency. In addition, they were also in agreement with the theory as the maximum power transfer occurred when the total length of the monopole was quarter-wavelength at 2.45 GHz. The antenna was tested and investigated at high power conditions, experimentally and in the simulation. The comparison of the extracted lesion dimensions showed similar changes to a corresponding power or time.

The primary outcome of this study was the method of design, construction and validation of an uncooled monopole antenna as well as its corresponding simulation model. This was followed by successful lesions in liver tissue when energised in high power conditions. However, other salient achievements during the process were the meticulous characterisation method to achieve a reliable ablation system and the replacement of mimicking solution with minced liver for the construction of the antenna.

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