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Miniaturized Implantable Antenna for Drug Delivery System

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Extended Abstract

With the development of biomedical telemetry technology, there is a demand for compact and efficient devices in medical applications. Therefore, implantable medical devices (IMDs) have attracted the attention of researchers[1]. These IMDs utilize implantable antennas to achieve wireless connectivity. However, the design of implantable antennas faces challenges such as bandwidth enhancement, size restrictions, biocompatibility, patient safety, and detuning phenomena[2]. Researchers are continuously working to overcome these issues.

This paper presents the design and development of a miniaturized implantable antenna, tailored for integration within a capsule for use in drug delivery systems. The antenna dimensions are remarkably compact, measuring only 5mm x 5mm x 0.625mm. It operates effectively at dual frequencies of 2.45GHz and 5.8GHz. The lower frequency band is dedicated to communication purposes, while the higher frequency band is utilized for detection and sensing tasks. This design breakthrough enhances the antenna's functionality, enabling it to not only serve its traditional role in communication but also function as a sensor. This is achieved by the use of the second, higher frequency which provides a more precise understanding of environmental or physiological parameters.

In pursuit of meeting compact form factor requirements, a combination of antenna miniaturization methods has been implemented in the design and development of the implantable antenna. A patch antenna was chosen for its ease of prototyping, together with the coaxial feeding method. Meandering slots are then employed to effectively increase the electrical length of the antenna, contributing to size reduction. Furthermore, the selection of the Rogers 3010 substrate, featuring a high dielectric constant of 10.2, serves to further minimize the antenna's dimensions.To enable dual-frequency operation, shorting pins have been introduced. Moreover, an additional metasurface structure is employed to optimize performance across these two frequencies.

The implanted antenna underwent a thorough performance evaluation through simulation using the CST Microwave Studio platform. The analysis focused on the dual-band operation at 2.45GHz and 5.8GHz, as well as the assessment of the antenna's return loss within these frequency bands. To increase the understanding of the implantable antenna's functionality within biological tissues, detailed simulation studies were undertaken. Initial observations are based on a single-layer muscle model, providing insights into the antenna's behavior inside biological tissues. Results indicate that the antenna achieved an S11 of less than -10dB at both 2.45GHz and 5.8GHz. Furthermore, the antenna demonstrated a bandwidth of 18.7% at 2.45GHz and 3.4% at 5.8GHz in various scenarios. .

Continuing the exploration of the antenna for a drug delivery system, subsequent simulations introduce chemicals of varying concentration in the presence of pathological tissues, effectively creating a simulated tumor microenvironment. This meticulous evaluation serves a twofold purpose – assessing the antenna's sensitivity amidst changing environmental conditions and gauging its ability to serve as a drug delivery monitoring device within the restrictions of the micro environment including biocompatibility.

References

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