Wireless Power Transfer System in 24 GHz for Implantable Medical Devices

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In this paper, a rectenna for wireless power transmission operating in the 24 GHz ISM band was designed. Conventional implantable medical devices(IMDs) have the limitation of requiring periodic replacement through reoperation when the battery is depleted. To address this issue, a miniaturized antenna was integrated with the IMD to enable external power transfer.

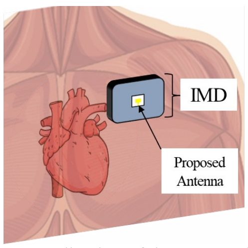

Fig.1. Application of the proposed Rectenna applied to an IMD

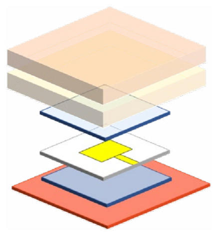

Fig.2. Visualization of the antenna integration within the human phantom model

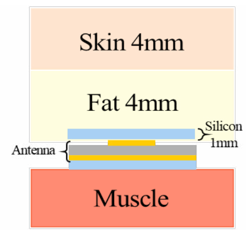

Fig.3. Schematic representation of the layer geometry model

Table I.
Electrical Properties of Materials

	ε_r	σ [S/m]
Skin	69.45	0.507
Fat	6.07	0.036
Muscle	65.97	0.708
Silicon	11.7	0.006

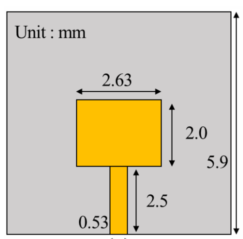

Fig.4. Design of the proposed Antenna

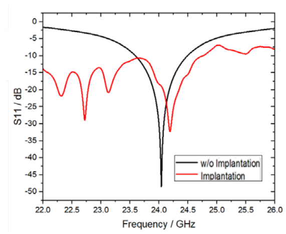

Fig.5. S-parameter analysis of antenna performance within the human phantom model

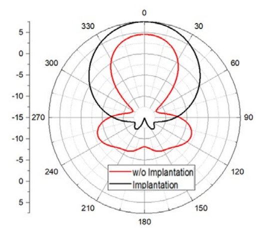

Fig.6.1 Simulated radiation patterns of the proposed antenna in E-plane at 24.1 GHz within the human phantom model

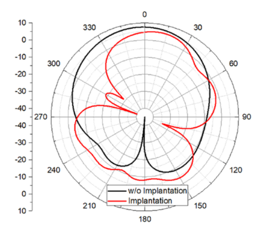

Fig.6.2 Simulated radiation patterns of the proposed antenna in H-plane at 24.1 GHz within the human phantom model

By modeling tissue similar to that of the human body[1] and performing simulations, the proposed design achieved an S11 of -32 dB at 24.2 GHz and a maximum gain of 4.58 dBi. Due to the high permittivity of body tissue, the effective permittivity increased, resulting in a reduction of the antenna size from 5.25mm to 2.63mm. Consequently, the resonant frequency was shifted from 24 GHz to 24.2 GHz.

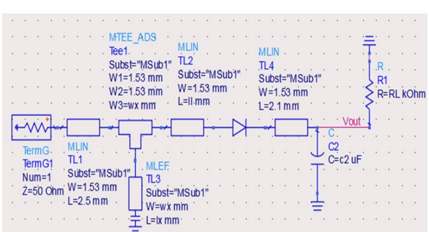

Fig.7. Schematic of the proposed RF-DC converter

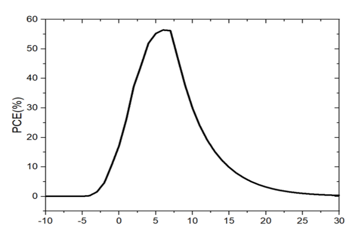

Fig.8. Simulated conversion efficiency of Rectifier in 24GHz

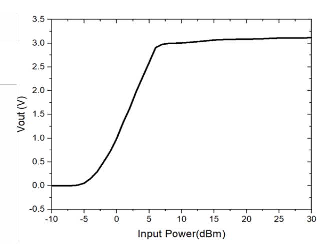

Fig.9. Simulated output DC voltage in 24GHz

The RF-DC converter was implemented using an open stub and a rectifier circuit, and its performance was further enhanced by incorporating an RF choke into the half-wave rectifier. As a result, the proposed system achieved a maximum power conversion efficiency of 56% and an output voltage of up to 3.0 V. Consequently, it was confirmed that the received power could be effectively stored through the antenna even in an in-body environment.

REFERENCES

[1] S. Salehin et al., "Rectenna-Based Wireless Power Transfer for Implantable Bioelectronic Devices," 2024 IEEE International Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE), Chennai, India, 2024