Design of an Electrically Small Wearable Antenna

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***Abstract*—An electrically small antenna is designed in this project, which is partially funded by the IEE MTT-S Undergraduate/Pregraduate Scholarship 2023. The scholarship funds were used to fund the work related to prototyping and validation of the device. The overall project consists of designing, fabricating and measuring the electrically small antenna for wearable medical devices with highly restricted size constraints and wide targeted bandwidth.**

***Index Terms*—Electrically small antennas, reconfigurable antennas, aperture tuning, wearable devices.**

I. Introduction

The goal of the work was to design a wearable antenna for medical devices. The size of such devices requires the use of electrically small antennas to produce a wearable device that does not hinder the user's day to day life.

The designed antenna is a modified version of the design by Ban et al. [1]. The size of the design was reduced by around 75%. To widen the available bandwidth a switchable matching network was implemented using RF-switches. The design is fed through a RF-port, through the chosen matching network (configuration 1 or configuration 2) to the patch antenna. The grounded section provides the low band performance to the design, by utilizing a meanderline structure beneath the ground plane, that can be seen in Fig. 1. A passive aperture tuning component was also added between the grounded strip and the meanderline section. This extends the electrical length of the structure in a compact manner.

II. Research and Results

Initial research has been done to source a antenna design, for which the radiation properties are retained, even when miniaturizing, and that can function in close proximity to a human torso.

During the simulation stage, satisfactory results were gained. For the reflection coefficient a -6 dB bandwidth of 901–933 MHz, in the low band, and 1.635–2.1 GHz, in the high band was achieved, shown in Fig. 4. Corresponding -10 dB total efficiency bandwidths were also achieved shown in Fig. 5. The bandwidth in the low band is not close to the target, but are supported by Chu-limit [2], that define bandwidth limits for ESA, and current literature. To achieve a satisfactory specific absorption rate (SAR) a copper plate and a Rohacell spacer were used to increase the separation between the antenna and the body phantom and to shield it.

A prototype of the antenna was fabricated, shown in Fig. 2, using equipment and guidance from Fablab Oulu. The case is a rough 3D-printed approximation of the product case, which could be used with the antenna design. It provides a suitable offset from the body phantom and protects the prototype. The PCB used was fabricated using a LPFK Protomat from a 1 mm thick FR-4 substrate. A body phantom, shown in 3, was fabricated to mimic the proximity to the human body during measurements.

For the measured reflection coefficient, radiation pattern and total efficiency were measured with the body phantom. The measured results were slightly better, achieving more separation for the two configurations in the low band and a slightly lower frequency. The measured bandwidth was 875–900 MHz in configuration 1, and 898–934 MHz and 1.72–2.2 GHz (24.5%) for configuration 2. The combined low band bandwidth is 875–934 MHz (6.56%).

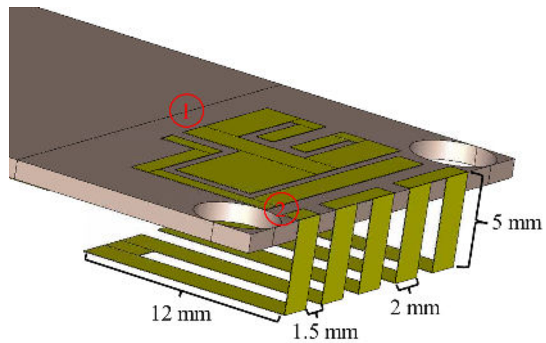

Fig. 1. Simulation model of the designed antenna, with the grounded meanderline structure below the PCB. 1) marks the feeding point and 2) marks the aperture tuning element position.

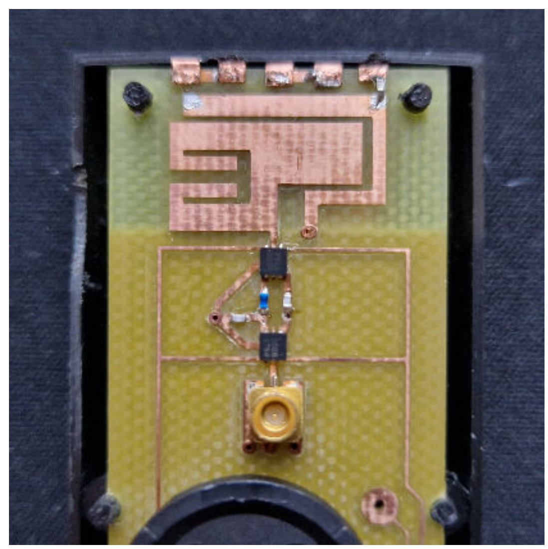

Fig. 2. Fabricated antenna.

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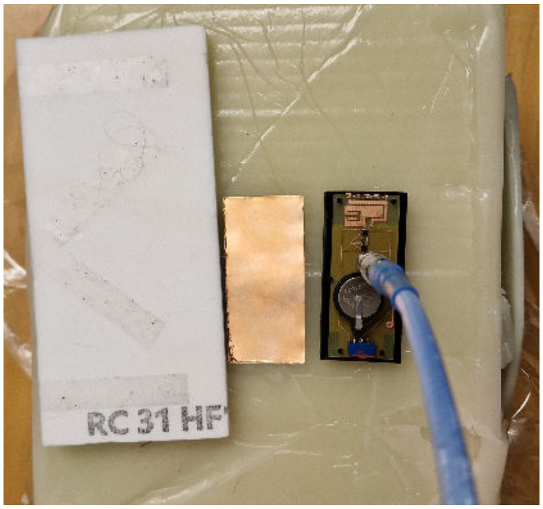

Fig. 3. Fabricated antenna pictured on the body phantom, with Rohacell spacer on the left side and copper reflector in the middle.

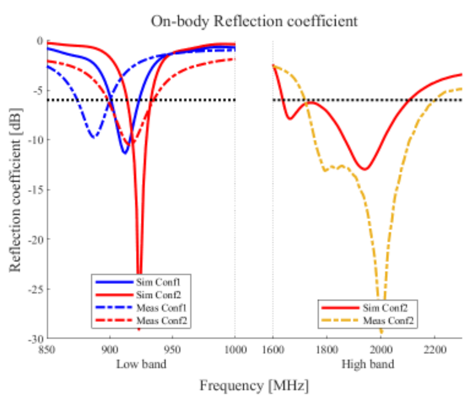

Fig. 4. Simulated and measured on-body reflection coefficient for both configurations, with the -6 dB line marked in black.

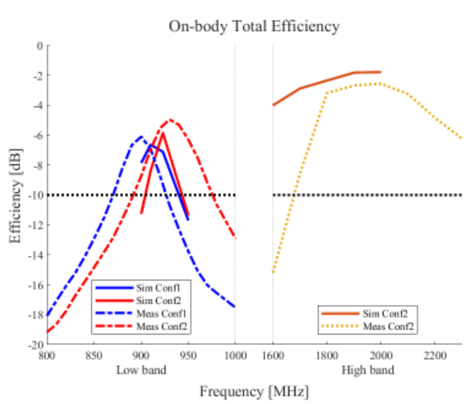

Fig. 5. Simulated and measured on-body total efficiency for both configurations, with the -10 dB line marked in black.

III. Publications

I have completed the a thesis entitled ”Design of a Reconfigurable Antenna for Compact Wearable Health Monitoring Devices” to complete my M.Sc. degree in the University of Oulu in June 2024. Derivative works from my masters thesis topic will be submitted to the IEEE Open Journal for Antennas and Propagation (OJAP) and to a Special Convened Session at EuCAP 2025.

IV. Career plans

For the future, I plan to work in the industry, but the scholarship has provided a great opportunity to see what academia requires. For the long term plan, I have not set anything in stone and working in academia is a possible path for me.

V. Acknowledgement

A special thanks goes to Ping Jack Soh and Kimmo Rasilainen for their help with various aspects of the project. Also I would like to thank Mariella Särestöniemi, for her help in providing a suitable body phantom for the measurements, Tung Phan, for helping operate the Satimo Starlab for the radiation pattern and efficiency measurements and Fablab Oulu, for providing the equipment and guidance in prototyping the design.

References

[1] Ban, Y., Liu, C., Chen, Z., Li, J. & Kang, K. Small-Size Multiresonant Octaband Antenna for LTE/WWAN Smartphone Applications. *IEEE Antennas And Wireless Propagation Letters*. **13** pp. 619-622 (2014)

[2] Chu, L. Physical limitations of omnidirectional antennas. *J. Applied Physics*. **19** pp. 1163-1175 (1948)