

R&D Item

6. Stochastic reliability Communication Technology in a Difficult Location to Communicate

Progress until FY2024

1. Outline of the project

We are investigating communication methods for CA in challenging environments such as inside the human body or underwater, where visibility is limited and radio waves are highly attenuated. In collaboration with the in-body CA project, we have initiated basic research aimed at realizing probabilistically reliable communication. This includes analyzing fluctuations and instability factors required for establishing communication with in-body CA and the communication and acquiring data from in-body CAs, which serve as a basis for enabling probabilistic teleoperation. As a use case, we envision a control scheme in which a small number of machine CAs are probabilistically selected from among millions of in-body CAs, and specific triggers are issued to control the CA group. When machine CAs are located outside the body or near the body surface, data transmission is performed through direct communication with smart spot cells. When they are located deep inside the body, communication is conducted via a separately installed external communication device. The volume of data exchanged between machine CAs and in-body CAs depends on the CA type and application. In this R&D project, we aim to develop communication technologies that ensure the reliability of teleoperation data transmission to probabilistically selected in-body CAs, based on a network configuration as shown in Fig. 1. We will also build a reliability-ensuring infrastructure, taking into account the development progress of the Arai Project, which is responsible for in-body CA hardware development.

2. Outcome so far

This year, we investigated research trends in in-body communication technologies and compiled examples of studies assuming various communication media. While many are still in early stages and have not reached the development phase,

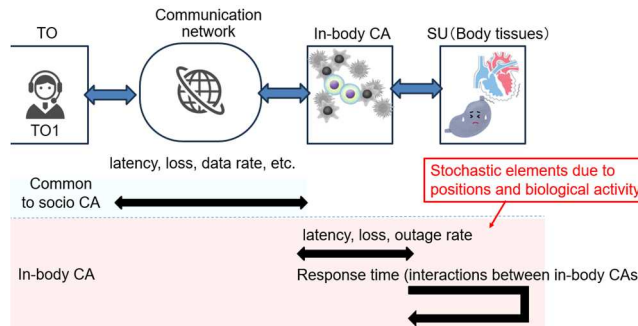


Fig. 1 Example of network configuration for in-body CA operation
we also summarized commercially available devices already in practical use or close to it, such as millimeter-scale swallowable thermometers and endoscopes.

The probability of successful communication strongly depends on factors such as system requirements, power supply, and device size, making it difficult to define a general indicator. Therefore, as a concrete case, we examined communication metrics based on the capsule-type in-body CA developed by Arai Project. We conducted link budget analysis under assumed requirements, using the measured radiation characteristics of the capsule CA. Since the capsule's position and orientation in the body vary depending on its location after swallowing, we calculated how changes in distance between the capsule and the receiving antenna on the body surface affect reception probability, considering fluctuations in received power (Fig. 2). Attenuation within human tissue was estimated using the IT'IS database [1], based on the tissue's relative permittivity and electrical conductivity. We also prepared for measurements using a human phantom and SAR (Specific Absorption Rate) evaluation liquid, which are scheduled for FY2025.

[1] <https://itis.swiss/virtual-population/tissue-properties/database/dielectric-properties/>

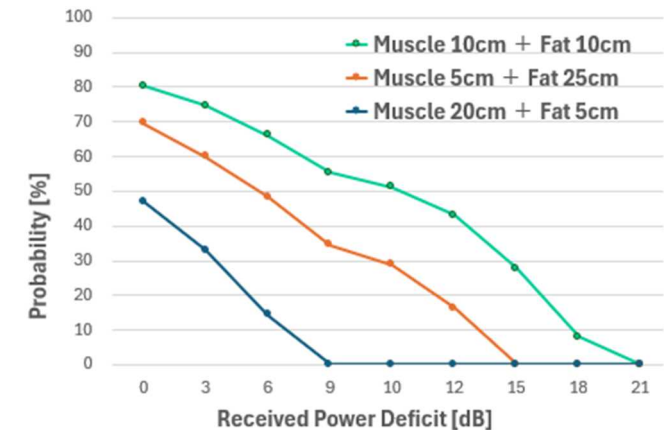


Fig. 2 Calculation example of communication success probability through human tissue

3. Future plans

To realize reliable communication with in-body CAs in challenging environments, we will continue studying communication technologies and applications such as testing and diagnosis based on probabilistic and statistical data communication. We will also model fluctuations inside and outside the body probabilistically and identify conditions that meet indicators defined for key use cases. In collaboration with the Arai Project, we will measure radio wave propagation in simulated in-body and external environments, assuming capsule-type in-body CAs. Based on the results, we will develop a probabilistic propagation model reflecting quality variations by angle and position, then design and test a new communication method using this model to confirm successful data transmission. As part of our basic research on next-generation in-body CAs, we will also co-develop implementation technologies for endoscopic CAs, aiming for practical in-body CA systems.