2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Tracking a Battery-Less Device by RF Signals for Functional Gastrointestinal Disorder Test*

Kenichi Takizawa[1], Ryotaro Suga[1], Shinichi Fujita[2], and Fumihide Kojima[1]

I. INTRODUCTION

Functional gastrointestinal disorders are common conditions in children and adults, often associated with abnormalities of whole gut transit. Currently, transit tests can be performed using several imaging methods, including tracking of radiopaque markers, gamma scintigraphy with the use of radioisotopes, magnetic tracking methods, and tracking of movement of wireless motility capsules with a battery[1]. In this paper, we propose a method for low-invasive transit test by tracking a battery-less swallowed device through radio frequency (RF) signals as shown in Fig. 1.

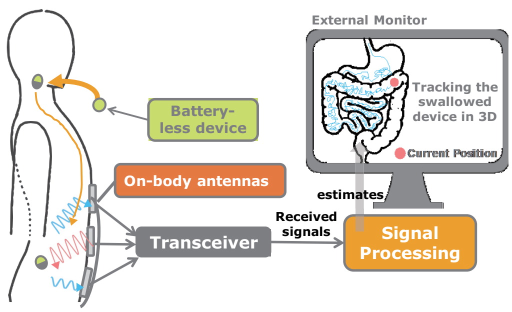


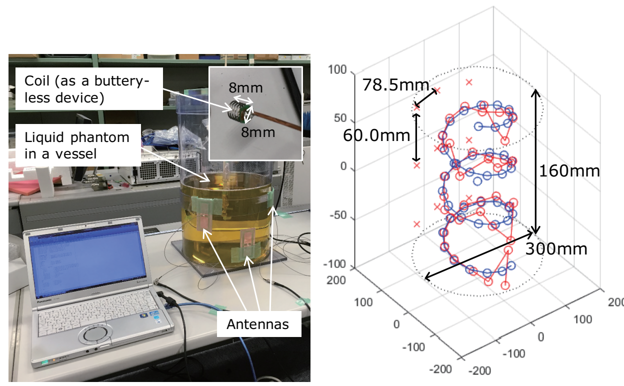
Fig. 1. Conceptual view of transit tests with the tracking method

II. TRACKING METHOD

If the swallowed device moves, phase difference $\Delta\theta_{i,j\neq i}$ is generated on received RF signals at the j-th antenna, which is transmitted from i-th antenna. By measuring the difference, travel distance of the device is calculated as $\Delta l = \lambda\frac{\Delta\theta_{i,j}}{2\pi}$, where λ means wavelength. Based on this principle, log-likelihood on existence of the device at (x, y, z) is given by $L_{i,j}(x,y,z) = -\frac{\sigma_n^2}{A_{i,j}}(\Delta\theta_{i,j} - \Delta\Theta_{i,j}(x,y,z))^2$, where $A_{i,j}$ is amplitude of RF signal and σ_n is standard deviation of noise. $\Delta\Theta_{i,j}(x,y,z) = \beta\cdot\Delta l = \beta\sqrt{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2}$, where (x_0, y_0, z_0) is reference location. By summarizing the log-likelihood among all the antennas, estimates on location $(\hat{x}, \hat{y}, \hat{z})$ are determined as $(\hat{x}, \hat{y}, \hat{z}) = \arg\max_{x,y,z}\sum_{i,j\neq i} L_{i,j}(x,y,z)$.

III. EXPERIMENT

An experiment has been conducted by using a liquid phantom, which is contained in a cylindrical vessel (diameter is 300 mm). The phase of received RF signals is measured by a vector network analyzer. Fig. 2 shows a setup and results of the experiment. As a battery-less device, a coil with a diameter of 8 mm is used. The frequency is set to 920 MHz, and the bandwidth is 1 MHz. The wavelength is 44 mm in the liquid phantom (conductivity is 1.05 S/m and relative permittivity is 54.8 [2]). Transmit power is 10 mW, which is less than 10% of that in mobile phones. As shown, the coil is placed along a spiral with diameter of 80 mm in the phantom by a XYZ-stage. Estimates are plotted by red circles when 9 antennas (3×3-array) are placed on the surface of the cylindrical vessel. Plots by blue circles show the true positions of the coil. RMSE (root mean squared error) over all the estimates is 13.1 mm.



(a) setup (b) results (red cross: antennas)

Fig. 2. Setup and results of the experiment with a liquid phantom (red circles: estimates, blue circles: true positions)

IV. DISCUSSIONS AND CONCLUSIONS

The results on tracking accuracy obtained by the experiment suggests that the method by using a small-sized swallowable battery-less device through measurement of RF signals has capability of realizing a low-invasive transit test. The experiment has been conducted in the liquid phantom, which is a homogeneous medium on the electric characteristics. The next step is to show results on a phantom with multi-layered mediums that mimics body tissues precisely.

REFERENCES

[1] H. Sharif, D. Devadason, N. Abrehart, R. Stevenson and L. Marciani, "Imaging Measurement of Whole Gut Transit Time in Paediatric and Adult Functional Gastrointestinal Disorders: A Systematic Review and Narrative Synthesis," Diagnostics, Dec. 2019.

[2] FCC, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," Supplement C (Edition 01-01) to OET Bulletin 65.

*This work was not supported by any organization

[1]Kenichi Takizawa, Ryotaro Suga, and Fumihide Kojima are with National Institute of Information and Communications Technology (NICT), Yokosuka, Japan takizawa@nict.go.jp

[2]Shinichi Fujita is with EA Pharma Co., Ltd., Tokyo, Japan fujita@eapharma.co.jp