Wireless Power Transfer System Using NFC for IoT sensors on the Fingertip

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Abstract: With the growing aging society, extending healthy life expectancy has been attracting attention. Small devices using IoT and wireless technologies are expected to have effect on self-health management. However, batteries and power cables cause problems such as the restriction on human motion or the devices’ size. Therefore, wireless power transmission (WPT) addresses these problems and use of WPT may help with improving daily health care management. In this paper, we propose a WPT system between mobile devices and a sensor on the fingertip by using Near Field Communication (NFC). The proposed system can transfer enough power for IoT sensors.

Keywords: Wireless power transmission, NFC, human body

Classification: Antennas and propagation

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1 Introduction

With the growth of the aging society, medical technology has become more advanced, leading to extending healthy life expectancy. Thereby, daily health management is gaining a lot of interest, and the utilization of IoT devices in the medical field is expected. As for the IoT devices, use of wearable devices has spread across the world, and is one of the impetuses for providing personalized medical care. Because most people across the world have Information and Communication Technology (ICT) devices [1], it is possible to gather a lot of data, create personalized information and manage health care through wearable devices by themselves. Currently, practical wearable devices can measure the pulse, blood oxygen saturation, and activity amount. To monitor vital data continuously, devices need to be always worn. Therefore, such devices need to be small and comfortable. Some antennas for small devices, such as wearable devices, have been proposed [2, 3]. These antennas, however, are a little bigger and thicker than the daily wearable antennas. The main problem is the power supply. If the devices contain batteries, they are larger and heavier. It is also difficult to supply power through a cable because the devices are always worn.

Thus, wireless power transmission (WPT) can be potentially used as a power supply. It is possible for a user to move freely without cables and exchange batteries. Moreover, it is possible to make the devices small and constantly monitor vital data. However, practical wearable devices using the WPT system, such as smartwatches, need to be charged after removal from the user.

In this study, we propose the WPT system between the sensor on the fingertip and the mobile devices by using Near Field Communication (NFC). Application of NFC has spread across most mobile devices. While the mobile device is in use, its antenna transfers power to the sensor on the fingertip. The sensor can monitor not only vital data but also the finger motion to control devices, and it is possible to utilize it for daily activities as well as medical activities. In [4], we simulated the proposed system by using the proposed square spiral coils. In this paper, we fabricate the antennas and conduct a measurement of the proposed system.

2 Proposed system

Fig. 1 shows the configuration of the proposed system. The proposed system assumes that a device with a transmitting antenna transfers power to a receiving antenna on the fingertip while the device is in use. Assuming that the finger is placed on the back of the device, the human body simulates the configuration of the index finger. The power supply uses the magnetic resonance method and the desired frequency is 13.56 MHz. This is because the magnetic field is hardly affected by the human body. The desired power is 1.0 mW as the sensors installed
in the IoT devices operate from several tens of µW to hundreds of µW. In the NFC forum, the wireless Charging Specification (WLC) enables an NFC antenna in an NFC-enabled device to charge low-power IoT devices [5]. The maximum transmitting power is 1.0 W in the WLC signification. Thus, the proposed system is evaluated by the receiving power when the transmitting power is 1.0 W.

The transmitting antenna is aligned with the center axis of the receiving antenna located on the phantom. Because the transmitting antenna and the receiving antenna do not touch the human body directly, the space between the phantom and the antennas is a simple air gap. The gap between the phantom and the receiving antenna is 1.0 mm, which is approximately the thickness of components including the sensor and circuit. On the other hand, the gap between the phantom and the transmitting antenna is 3.0 mm, which is the approximate thickness of the device cover or other elements of the device. In the measurement, a styliform was installed in the air gap.

The electrical constant of the phantom is that of a saline phantom (relative permittivity, $\varepsilon_r$ 78; conductivity, $\sigma$ 0.4 S/m [6]), whose electrical constant is close to that of the two-thirds muscle-equivalent phantom. The proposed system is simulated by frequency domain solver of CST MW-Studio 2020 [7].

![Figure 1. Proposed system](image)

### 3 Simulation and fabricated antennas

The analysis models and the fabricated antennas are shown in Fig. 2 (a-b). The transmitting antenna is installed in the existing mobile device. Thus, the antenna design standardized in the NFC forum [8] is applied as the transmitting antenna. As for the receiving antenna, its size is within 10.0 mm×14.0 mm because the receiving antenna is placed on the index finger. Both antennas are a square spiral coil with a FR4 substrate (relative permittivity, $\varepsilon_r$ 4.3). Additionally, analysis results do not take a conductor loss into account.

The impedance matching largely affects antenna performance because the antennas are small with respect to their wavelength in NFC. Thus, in this system, both antennas have a matching circuit, which matches at 50 Ω. The matching circuit is shown in Fig. 2 (c), where C1 is 19.8 pF, C2 is 172.0 pF, C3 is 1150.0 pF and C4 is 82.0 pF. The value of the capacitors was used for Murata Manufacturing.
4 Simulation and measurement results

To compare antenna performance with the analysis results, the simulation results of the antenna alone in air were used. As for the fabricated antennas, these antennas were adjusted by changing the values of the capacitors in the measurement when the antennas were in air. In the measurement, C1 was 20.2 pF, C2 was 174.0 pF, C3 was 1197.0 pF, and C4 was 100.0 pF.

The analysis and measurement results are shown in Fig. 3. The blue line is the analysis result in air, the red marker is the measurement result in air, and the green marker is the measurement result on phantom. Port 1 is installed in the transmitting antenna, and port 2 is installed in the receiving antenna. $S_{11}$ shown in blue is -27.3 dB, $S_{11}$ shown in red is -8.5 dB, and $S_{11}$ shown in green is -8.0 dB. $S_{22}$ shown in blue is -19.2 dB, $S_{22}$ shown in red is -12.1 dB, and $S_{22}$ shown in green is -11.6 dB. There is almost no difference between the result in air and the result on phantom. For $S_{11}$ and $S_{22}$ results, both antennas can be used at 13.56 MHz.

As for the transmission efficiency, $S_{21}$ in the simulation is -7.4 dB at the desired
frequency. When the transmitting power is 1.0 W, the receiving power is 182.0 mW. This receiving power is sufficient power for IoT sensors. In addition, at the transmitting power of 1.0 W, the area in which the receiving antenna can receive 1.0 mW is within a range of ± 28 mm in the x direction and ± 25 mm in the y direction from the center axis of the antennas. On the other hand, $S_{21}$ is -16.4 dB at the desired frequency in the measurement. When the transmitting power is 1.0 W, the receiving power is 22.9 mW. This result meets the requirement, whereby the receiving power is at least 1.0 mW. There is a difference between the analysis result and the measurement result. However, the existence of the phantom and the length of the coaxial cables have no influence on the results. Thus, it is probable that the conductor loss was remarkable in the measurement.

As a result, the proposed system in both simulation and measurement can transfer enough power to drive the IoT sensors when the transmitting power is 1.0 W.

![Reflection coefficient and transmission coefficient](image)

5 Conclusion

In this paper, we proposed a wireless power transmission system between a sensor on the fingertip and mobile devices operating at 13.56 MHz. The analysis and fabricated antennas can be used at the desired frequency. Although there is the difference in transmission efficiency between the analysis results and the measurement results, it is probable that the conductor loss is remarkable in the measurement. As a result, it is confirmed that the proposed system can transfer enough power to drive the IoT sensors. In future works, considering implementation, the receiving antenna will be optimized by using thin and flexible materials.