Data communication method based on inaudible sound at near field

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Abstract— **In this paper, we proposed data communication method based on inaudible sound which the most people cannot listen to at near field. The proposed method can transmit some bits data as using mixed high frequencies which are mapped at each data bit. Besides, the proposed method increases the accuracy of data transmission as using cyclic redundancy check for prevention of transmission error. To evaluate the performance of the proposed method, we tested with the proposed method and the result showed 97.5% accuracy. Therefore, the proposed method could be applied at various wireless data communication technology fields.**

***Keywords*— Inaudible frequency, wireless communication, Data communication, Mobile information, Data transmission**

I. INTRODUCTION

Recently, technologies of mobile devices and wireless communication are developed rapidly. Wireless communication technologies such as Near Field Communication (NFC) and Bluetooth which are built in smart phones or tablet PCs are used at the payment system, near file transmission, and information supply [1, 2]. However, those have to need NFC module or Bluetooth module for using the wireless communication. Thus, iPhone or iPad cannot do wire communication via NFC, because those are not built in the NFC module. Besides, Bluetooth cannot work between smart device based on Android Operating system (OS) and smart device based on iOS, because Bluetooth only works at the same OS. To solve this problem, many researchers have suggested various studies using high frequencies which are over 18 kHz. However, because the most studies using high frequencies can transmit a small data between smart devices only, wireless communication technologies using inaudible sound are very seldom used [3, 4].

In this paper, we proposed a novel inaudible frequency communication method which can transmit more data using high frequency sound waves. The data transmitting devices is set to the frequency which is a unique mapping of data bit, and transmit signal by converting data after encoding mixture of each specified frequency. The data receiving devices confirm the inaudible frequency contained in the signal, and verify data by decoding the bit values mapped into the corresponding frequencies. We use the technique of Cyclic Redundancy check which is used for the error detection in the data communication in order to prevent transmission errors that may occur in the process [5]. We developed a web page based on JavaScript to check data transmission performance of the proposed method transmitting data from PC, an application based on iOS receiving data from smart devices and performed the experiment using them. The experiment result shows the transfer accuracy rate of 97.5%, and it detects the data transmission error of 2.5%. In other words, the presented method can be proved as a useful way to overcome the transmission limit with the wireless communication technology using the existing inaudible frequency.

This paper is organized as follows. In Section 2, we explain the existing researches that use the inaudible frequency. In Section 3, we describe the system configuration and signal processing method. In Section 4, we explain the experiment and the result via JavaScript-based web page and iOS-based application developed using the presented method, followed by the conclusion and by the future approach in Section 5.

II. RELATED WORKS

This section describes how inaudible frequencies are used to data communication in the related researches. Kim proposed a smartphone user authentication method using the inaudible frequencies [3]. This generates one designated frequency for each channel using stereo channels, it is recognized as one challenge when it observes 4^{th} bit for the combination of two frequencies. It takes a total 8 seconds to recognize double bite challenge once. This method can eliminate inconvenience by using the smartphones as hardware tokens, it complement the shortcomings of the existing authentication methods. However it is inappropriate for the data transmission due to the slow transfer rate.

Bihler presented a smartphone application and system for transmitting the information to users in the museums using inaudible frequencies [4]. This system is aware of inaudible frequencies generated from the piezoelectric speaker which is installed in a museum, then provides the information to the user receiving them from the web server. He used two frequencies of 20 kHz, 22 kHz for data communication. It took 26 ms to transmit one bit, and can send a total of 8 bits for 208ms. Besides, Bihler used a Hamming code together to protect the error which can be occurred in data communication [6]. But using the method presented by Bihler, incorrect data are transmitted frequently. There is a problem the noises are generated from the piezoelectric speaker when converting the frequencies quickly in a short time.

III. PROPOSED METHOD

We describe the encoding way from bit data to audio signals and the decoding way from audio signals to bit data using inaudible frequency to transmit data. The inaudible frequency in this presented method uses from 18 kHz to 22 kHz, the bits organizing data are mapped to the different specific frequency, they have 50 Hz guard band at each side of the mapped frequency to avoid interference between bits. Thus a bit can be represented in 100Hz, it can transmit 40 bits data between 18kHz and 22kHz used in the presented method. The frequency mapped with each bit has the rule of the equation 1 as follows.

$$f = 18050 + 100\ n\ (n=0, 1, ..., 39) \qquad (1)$$

In Equation 1, f refers the value of inaudible frequency for 1 bit expression, ***n*** is a number to create 40 frequency. Data encoding generates the complex frequency signal mixing frequency mapped of data value 1. Figure 1 explains the process of generating the complex frequency signal mixing with two single frequency signals. Figure 1 shows briefly the two frequencies f1 and f2 are mixed, up to 40 different frequencies could be mixed using the presented method, the mixed frequencies through FFT analysis are expressed in Figure 2. Figure 2 explains 10011100 10110100 01100111 01100011 00001101 data, in front of the 32 bits show the data to transmit at this time. The rest of the 8 bits are cyclic redundancy check data to examine the error when can be occurred during data transmission.

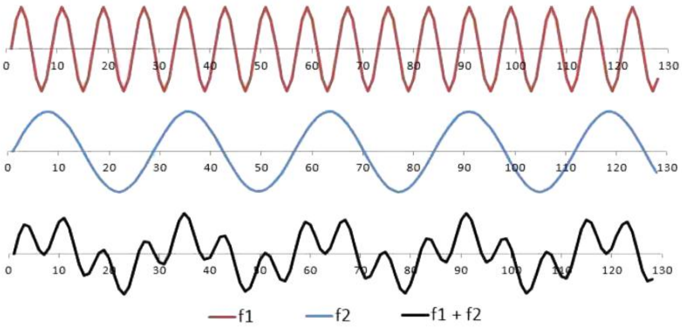

Figure 1. An example of mixed frequencies with f1 and f2

The next step is decoding the signals after taking them via microphone of the data receiving devices. The time required to receive data can be determined by the number of sound samples used for decoding. It will take 0.17 seconds if 8,192 samples are used, since it is possible to recognize 48,000 samples per second[7-9]. After that, it extracts a frequency included in the signal from the FFT conversion from the recognized sound sample. It the signal contains the frequency mapped to the bit, the value is represented by 1, otherwise it has a value 0. Figure 3 is a graph analyzing FFT after receive data of figure 2 from smart devices. Figure 3 shows that transmitting data in Figure 2 has the similar type to the FFT value, the received values are used to decode the actual receiving data by modifying On-off keying techniques [10]. We can tell the frequency rate of valid Frequency bin is at 18.05 kHz, 18.35 kHz, 18.45 kHz, 18.55 kHz, 18.85 kHz, 19.05 kHz, 19.15 kHz, 19.35 kHz, 19.75 kHz, 19.85 kHz, 20.15 kHz, 20.25 kHz, 20.35 kHz, 20.55 kHz, 20.65 kHz, 21.05 kHz, 21.15 kHz, 21.65 kHz, 21.75 kHz, 21.95 kHz shown in Figure 3. Therefore the transmitted data value decoded by a defined protocol is 10011100 10110100 01100111 01100011, the data for the check of cyclic redundancy error is 00001101, with this result we can confirm the data is transferred correctly.

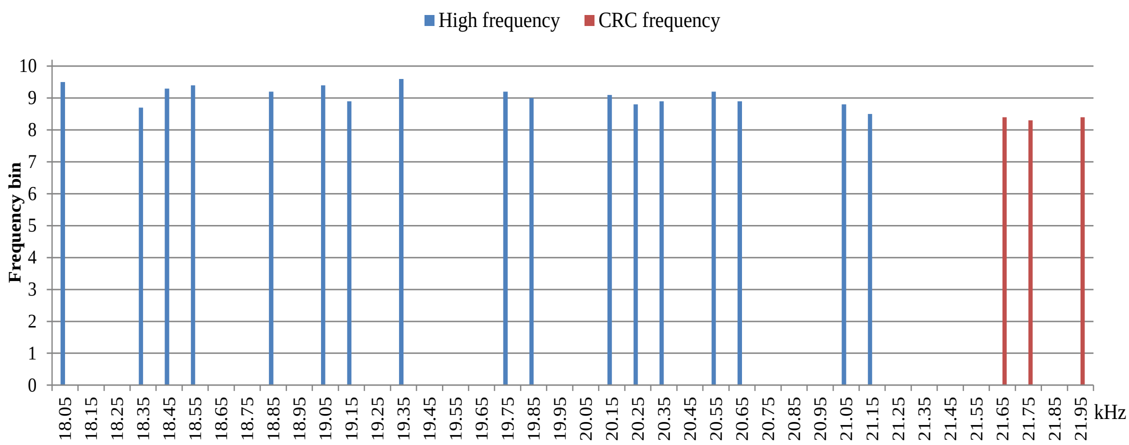

Figure 2. An example of high frequency sound which include transmission data and checksum

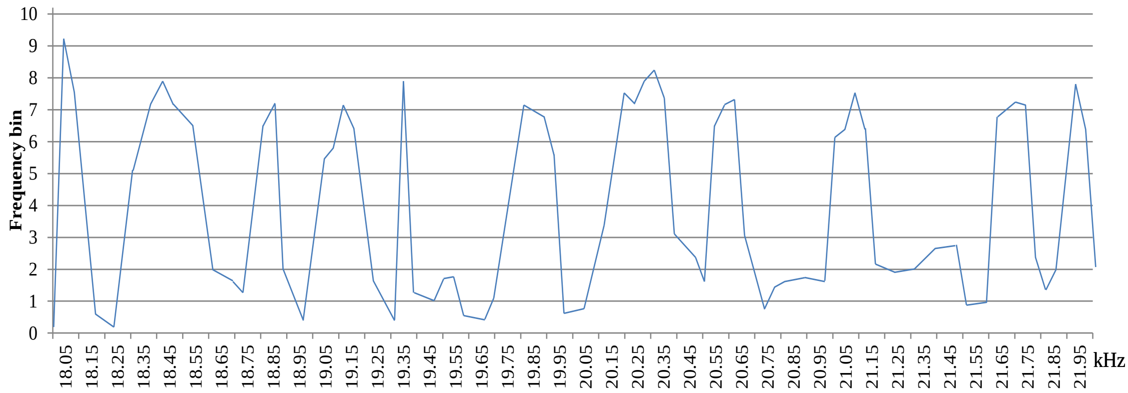

Figure 3. An example of FFT analysis result at the smart device which is received high frequency data

IV. THE EXPERIMENT AND THE EVALUATION

We conduct the experiment and the evaluation to affirm data transfer performance of the presented method in this chapter. We created the JavaScript-based web page to confirm the data transmission performance of our method which transmits data from PC. We used two data as follows

Data 1 : 11000100 00100010 00110100 10101010 11111010
Data 2 : 10100110 11101101 11010010 10010001 10100010

The above Data 1 and Data 2 can be output frequency for 0.5 seconds when it generates for data transmission once.

The iOS-based application to receive data is shown in Figure 4. When a user touches the Start data share button in Figure 4, the application will continue to analyze the ambient sound in the near field.

The FFT Library algorithm implemented by Baoshe Zhang[11] is used in the application to analyze FFT. Received data and received CRC value shown in Figure 4 tells that they will receive Data 1.

Then, we conducted the experiment to analyze the performance of the proposed method using the JavaScript-based web page and iOS-based application which is implemented in this study. Experiments are done in the laboratory environment having 50 dB noise which can be called a quiet level in everyday life. We define the sound as 70 dB from PCs to smart devices to transmit data. We send wireless communication Data 1 and Data 2 100 times each, we received the data at smart device. The result is shown in Table 1.

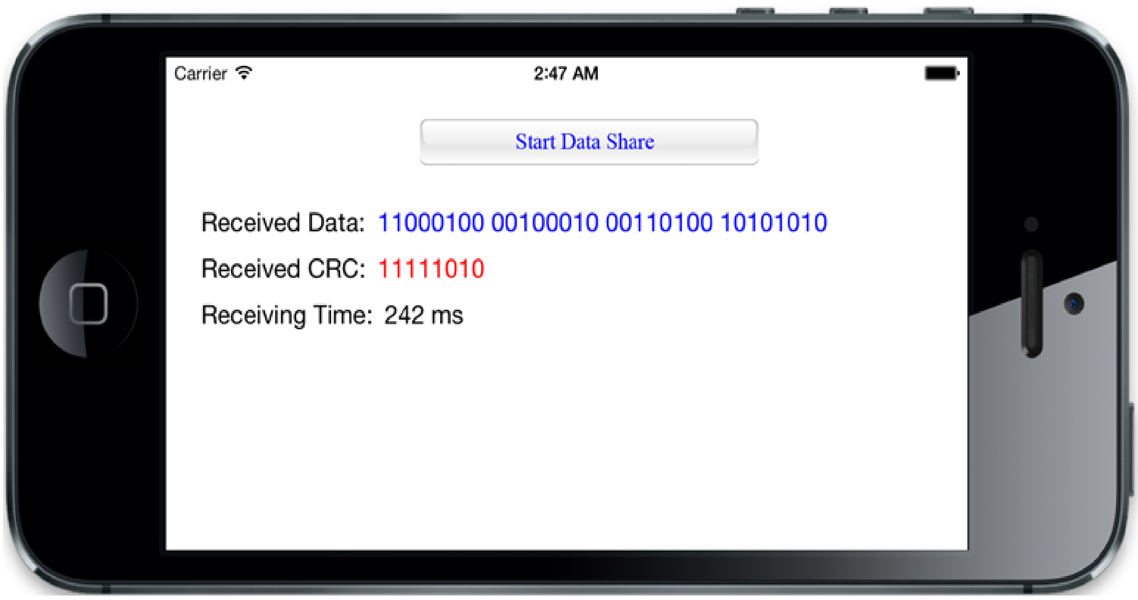

Figure 4. Screen capture of the application which receives inaudible sound

TABLE 1.

	Success	Fail	Error detection	Average time
Data 1	98	0	2	243 ms
Data 2	97	0	3	234 ms
Average	97.5	0	2.5	238.5 ms

As described in Table 1, the number of successful reception is 98, 97 and there is no reception failures. We can check that it prevents the error by the cyclic redundancy check of 2~3 times for each signal which is not received successfully. In other words, it shows the data transmission success rate as average 97.5%, the failure rate is 0%.

V. Conclusions

In this paper we presented a novel method useful for communication mixing a number of single inaudible frequencies to multi-frequency signals. As a result, we ensure that it is faster than the existing methods transmitting 40 bit data in 240 ms and the transfer accuracy is high. Besides, It does not generate noise without rapid frequency change, it has a strong point it is possible to recognize again even though it fails to recognize data. The wireless communication using the inaudible frequencies could be applied to more various fields via this technique. In future works, we will study the data transmission algorithm to send more data continuously per unit time using this method.

Acknowledgment

This research was supported by Next-Generation Information Computing Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 2012M3C4A7032783 and NRF-2013R1A1A2061478).

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