Beat Sensors for Smart Environment Monitoring Systems

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Abstract—**This paper introduces Beat Sensors which are suitable for smart environment monitoring as low power and small size IoT sensors. As a typical representative, the Ethanol Beat Sensor is realized to monitor the ethanol concentration from 0 to 200 ppm at almost 20 ppm resolution. Beat Sensor has large potential to address issues of smart environment monitoring such as air pollutions management. Moreover, the long distance (LoRa) communication protocol is applied to build a smart and energy efficient monitoring system.**

Keywords—IoT, IoT Sensor, Beat Sensor, Smart Monitoring, LORA

I. INTRODUCTION

Air pollution is one of big issues among major cities especially in developing countries. According to WHO [1], over 80% of urban residents are exposed to air pollution level more than WHO standard, and air pollution has killed 7 millions of people every year. Monitoring the air pollution by IoT technology has a large potential to address the issue, so that governments and people get to know how much and where the air pollutions occur through the internet and can do something to reduce the pollutions or escape from the pollutions. So, IoT sensors which consistently monitor the air pollutions are required.

We propose various types of Beat Sensors [2-5] for low power, small size, low cost IoT sensors. We have already realized many kinds of Beat Sensors such as Temperature Beat Sensor [2], Power Beat Sensor[3], DC current Beat Sensor [4], Beat Sensors for monitoring water quality [5] and so on.

In this paper, we demonstrate the Beat Sensors which has the best potential to monitor the air pollutions with low power, small size and low cost, so that numerous numbers of sensors could be distributed to the smart environment monitoring systems. As the first air pollution Beat Sensor, we demonstrate the operation of Ethanol Beat Sensors. Beat Sensors for monitoring such air pollution as CO, H2S, NOX could be realized by the same way as the Ethanol Beat Sensor. Moreover, the long distance (LoRa) communication protocol is applied to build a smart, energy efficient and long distance environment monitoring system.

II. BEAT SENSORS CONCEPT

Figure 1 shows the structure of the Beat Sensor and ID code timings from the Beat Sensor Node. In the Beat Sensors, Ethanol, air pollution gas, or temperature sensors are attached to transmitter for each, which is assigned by each ID code. Unlike conventional IoT sensors, the transmitter transmits only ID signals, interval times of which corresponds to the physical parameter of the sensor. The receiver receives the ID signals, and calculate the physical parameter by the interval times of the ID signals.

In experiments, we have succeeded in getting data for more than three months with small lithium coin battery, and one receiver can get the data simultaneously from 8 sensor nodes.

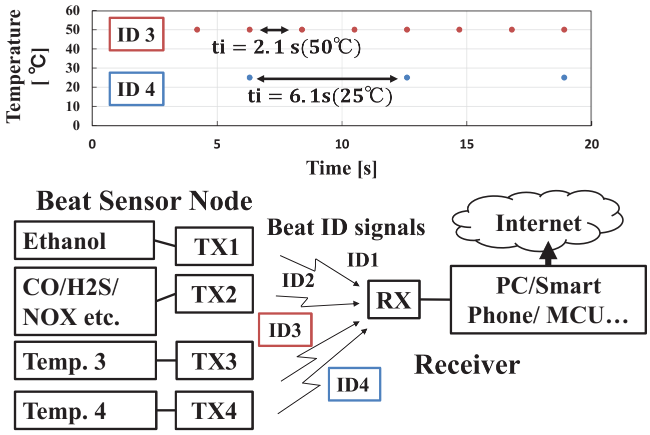

Fig. 1. Beat Sensor concept.

III. STRUCTURE AND OPERATION OF THE ETHANOL BEAT SENSOR

Fig.2 shows structure of the Ethanol Sensor node. We utilized an ethanol sensor of ULPSM-Ethanol 968-007 of SPEC SENSORS LLC [8]. The sensor puts out the Vgas and Vref signals, so that the Vgas – Vref values correspond to concentration of Ethanol in the air. These voltages are operated by the operational circuit, where output of the circuit Vo becomes

$$Vo = Vb + (Vgas - Vref) \quad (1)$$

Vb in (1) is bias voltage. Vo is converted into interval times ti of the ID code by the operation of resistance, storage capacitor, and Schmitt trigger circuit.

Fig.3 shows operating waveforms of the Ethanol Beat Sensors. At the Ethanol concentration of 0 ppm, the interval time is almost 5.8s. As the concentration becomes high, the interval times becomes shorter, and ti becomes 3.8 s at the ethanol concentration of maximum 200ppm. The power consumption of the Ethanol Beat Sensor node is almost 0.3mW at a supply voltage of 5V. The interval time of the ID signal depends on the ethanol concentration, as shown in Fig.4.

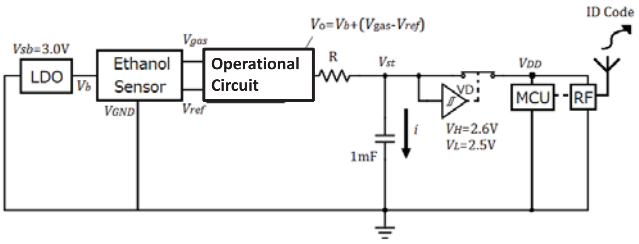

Fig. 2. Structure of Ethanol Beat Sensor node.

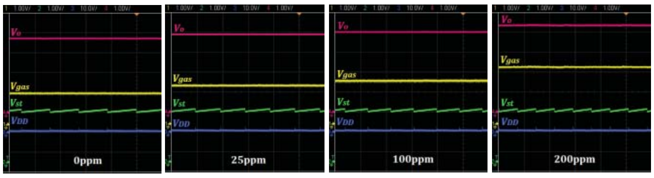

Fig. 3. Operation waveforms of the Ethanol Beat Sensors.

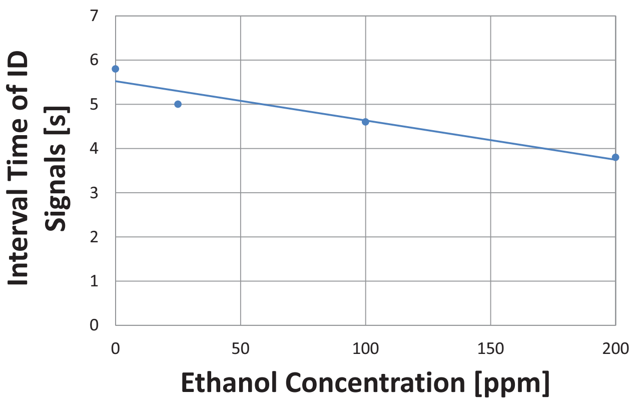

Fig. 4. Interval time as a function of Ethanol concentration.

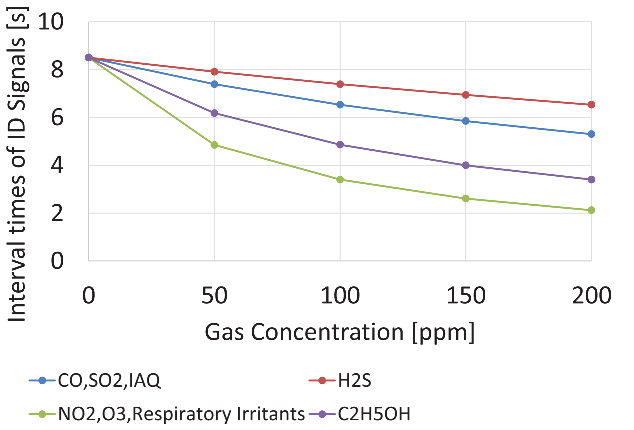

Fig. 5. Interval times of ID signals depending concentration of air pollution gases.

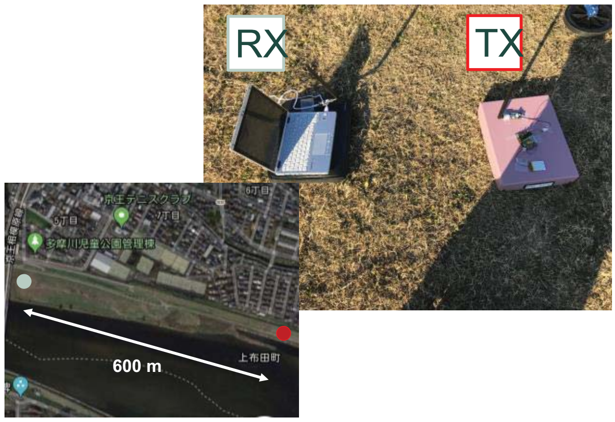

Fig. 6. IoT based monitoring system with Beat sensors and LORA protocol.

IV. SENSITIVITY OF AIR POLLUSION CONCENTRATIONS

Usually air gas sensor has cross sensitivity, which means that the sensor has some amount of sensitivity for different gases from the target gas. As for the ethanol sensor we are utilizing has a lot of cross sensitivity to such kinds of gasses as CO, NO2, O3, H2S and so on. So the Ethanol Beat Sensor can be used as sensor for those kind of gases.

Fig.5 shows calculated sensitivity of the Ethanol Beat Sensor. The Beat Sensor has cross sensitivity for such gases which introduce air pollutions.

V. LONG DISTANCE AND ENERGY COMMUNICATIONS WITH LORA AND BEAT SENSORS

For long distance IoT monitoring system, we propose the use of LoRa communication method for Beat sensor applications. In order to implement the proposed system, the AcSIP LoRa WAN EVK+Antenna KIT S76SXB of the ACSIP Technology Corp was used. This development kit can be considered as a really effective platform for the popose of technical developing and testing of the AcSIP S76S SIP LoRa module employing LoRaWAN protocol. Fig.6 shows the system deployment scheme.

Fig.7 presents the implementation results with the probability of successful data transmission rate for two cases of bandwidth. Fig.8 shows the results of energy consumption of LoRa module with bandwidth of 500KHz. It can be seen that the LoRa based sensor module can achieve very low energy consumption.

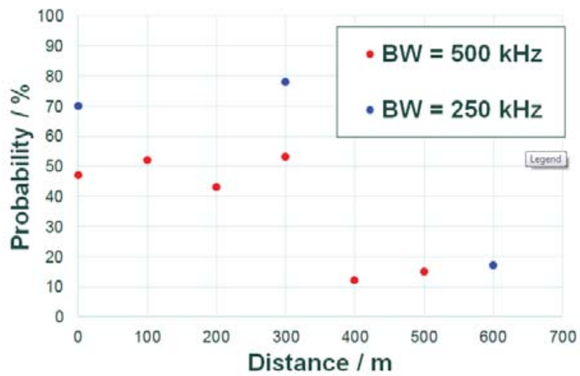

Fig. 7. The results successful probability of LoRa based monitoring system using Beat sensors.

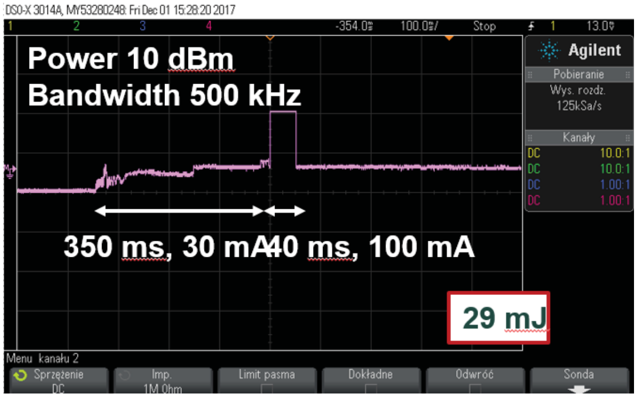

Fig. 8. The results of energy consumption of LoRa module with bandwidth of 500KHz.

VI. Conclusions

This paper presented Beat Sensors for smart monitoring systems such as air pollution gases. The Ethanol Beat Sensor can successfully monitor the ethanol concentration from 0 to 200 ppm. The sensor can be applied to monitor the concentrations of another kinds of air pollution gases, such as CO, SO2, NOX and so on. Beat Sensors as low cost, low power, and small size IoT sensors, have large potential to address issues of air pollution of cities. Moreover, LORA communication protocol was employed to build a smart, long distance and energy efficient monitoring system. For future research, we will consider to apply cryptography algorithms for efficient, secure and smart IoT based monitoring systems [9-10].

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