# Exploring Suitable Electrical Elements on Human Detection Sensor Using Electromagnetic Noise

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***Abstract*—To support a human by installing sensor and communication device is widely studied. Human detection is a key technology to trigger such a service. In some cases, the sensor is demanded to be installed into non-electrical object, such as a chair. To make it viable, how electrical power is supplied is problematic. If using commercial electrical power line, the location and mobility of the object are limited. If battery is used, maintenance cost of changing battery arises. Thus, we propose a human detection sensor using electromagnetic noise leaking from commercial power line. This sensor detects a human without electrical power supply, using electromagnetic noise in environment. In past research, basic operation principle is confirmed. However, values of electrical component of the sensor is not explored very well. In this paper, suitable parameters of its CW circuit and antenna are discussed. As a result, it is disclosed that suitable parameter for reverse current of diodes was less than 6 μA, and capacitance of capacitors was 100 pF. About the size of antenna, the larger output voltage is obtained by the larger size, while the difference of output voltage between presence and non-presence of a human gets smaller. The suitable size of antenna is concluded to be around 30 cm × 40 cm.**

***Keywords—human detection, electromagnetic noise, Cockcroft-Walton circuit, commercial power line, electrical element, antenna***

## I. INTRODUCTION

In recent days, many things around us have communication function to connect to the Internet, so-called Internet of Things(IoT). One of the typical services of IoT is smart home. In a smart home, Wireless Sensor Network(WSN) is created by things that has sensing and communication function in a house and support residents using obtained data. Several types of services are proposed on WSN. For example, health care, caregiving, efficient life and electrical power saving are proposed[1].

A sensor nodes on a WSN is consisted of sensor and communication module. These components require electrical power to operate. In case that sensing and communication function are implemented on equipment, supplying electrical power is required and problematic. When using power supply cord, the location and mobility of the equipment are limited by cord. When using battery, periodical or irregular maintenance operation, such as changing battery cells, is needed. Especially, it becomes quite difficult if many devices install in house. Moreover, the lifetime of battery is getting relatively longer, it becomes more difficult to remember and notice the need to change the battery. This can cause uncertain stop of the service. Battery-less sensor node solve these problem.

In case that device is without battery, electrical power is supplied from outside of device. Wireless Power Transfer (WPT)[2] and Energy harvesting (EH)[3] technique are way of electrical power supply from outside. WPT is technique that transmit electrical power without physical link. Transmitting efficiency depend on position of receiver coil and transmitter coil[4]. EH technique obtains electrical power from environment. For example, solar and wind, vibration, electromagnetic noise. A device that have EH function can operates semi-permanently. However, electrical power obtained by EH is unstable [5].

Decreasing electrical power consumption technique is well studied by software[6] and hardware[7]. A device operates by WPT and EH if power consumption is lower. Therefore, reducing electrical power consumption is important for developing battery-less system.

Data used in a smart home is a variety of types as well, such as temperature and humidity in a room, status of electrical equipment. Especially, presence of a user is one of the key information because it is often utilized as a trigger of services intended for user. For instance, the information is utilized for a security camera that shoots if someone approaches and a light that turns on if someone enters into a certain place. However, human detection sensor is difficult to decrease its power consumption. This is because the sensor consumes electrical power even though user are not there, because presence of a human is unpredictable event and the sensor needs to keep working everytime.

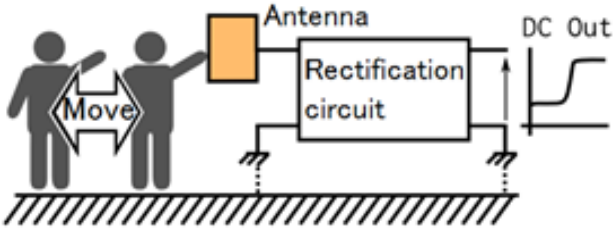


Fig. 1 Principle of human detection using electromagnetic noise. Output voltage get higher when human gets close to antenna.

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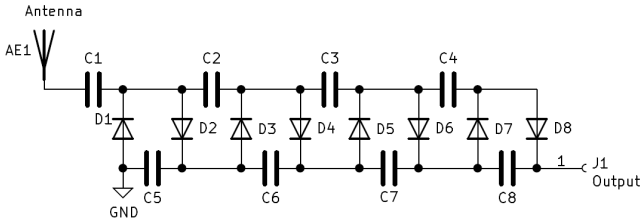



Fig. 2. Sensor circuit is configured antenna and CW circuit. CW circuit is 8 steps

Ohmura *et al.*[8] proposes a human detection sensor that works without any power supply. The sensor uses electromagnetic noise in the environment, which is leaking from the consumer electric power line, and detects a human by the output voltage difference between when a human is close to the sensor and not. Their study have showed its basic operation principle and basic evaluation in the paper.

The sensor is suitable for battery-less sensor node because it can reduce power consumption in device. However, detailed study on the parameters of electrical elements has not been studied very well. In this paper, we explore the parameters of electrical elements of the sensor. The sensor consists of a rectification circuit and an antenna. By changing several parameters of electrical elements of rectification circuit and material and size of antenna, suitable parameters are investigated in this study.

## II. Person Detection Using Electromagnetic Noise

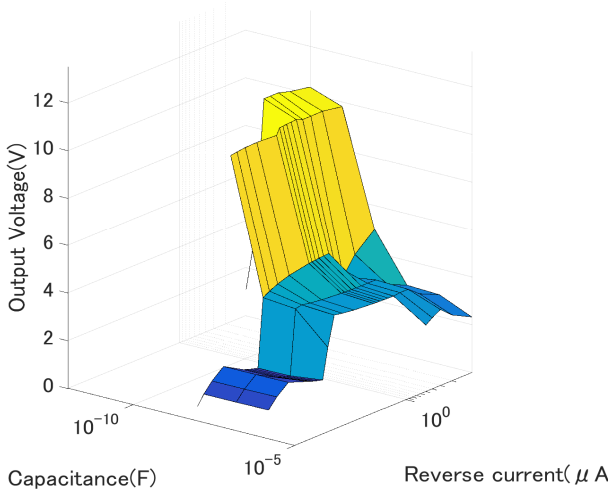
Ohmura *et al.* treat circumjacent noise as AC source of faint current and voltage[8]. They propose a human detection method using a technique of "converting AC signal to high voltage DC signal" and a phenomenon of "increasing output voltage of an antenna when a person gets close". An antenna receives leaking electromagnetic noise from commercial power line(50Hz/60Hz). The received electromagnetic noise is converted to DC signal by Cockcroft-Walton (CW) circuit, which rectify and boost its input signal without electrical power source. CW circuit do not require electrical power because it is consisted diodes and capacitors. As shown in Fig.1, voltage level gets higher because of apparently improving antenna's sensitivity when person body is close to the antenna. Thus, output voltage level of the CW circuits becomes higher than the one when a person is not around the antenna, and the sensor detects a person by the difference of voltage level. The sensor detects a staying person too. Antenna efficiency depends wavelength of signal. However wavelength that frequency is 50 Hz or 60 Hz is 5000 km or 6000 km. Making antenna length half or quarter of these is difficult too long. Therefore antenna is plate for the purpose coupling between antenna and human body.

TABLE I. Diode of Electrical Characteristics

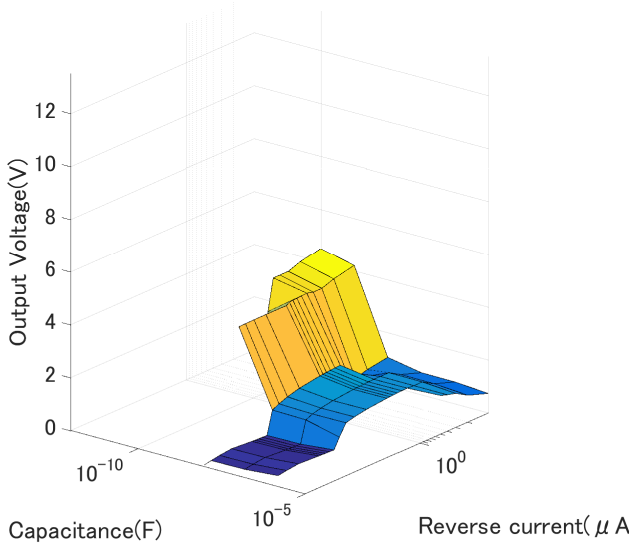
| Diode | Forward voltage (V) | Reverse current (μA) | Total capacitance (pF) |
|---|---|---|---|
| 1SS196 | 0.60 | 0.10 | 0.90 |
| DB3X313N0L | 0.55 | 50.0 | 3.80 |
| DB3X315E0L | 1.00 | 0.30 | 1.40 |
| 1SS321 | 0.32 | 0.50 | 4.50 |
| 1SS377 | 0.18 | 20.0 | 20.0 |
| DA3X103E0L | 1.20 | 0.10 | 2.00 |
| 1SS392 | 0.28 | 5.00 | 18.0 |
| SBR05U20SN-7 | 0.51 | 6.00 | - |

They evaluated effect of distance between human and antenna to show detecting human by them proposed method. They showed that theirs method detects human. In addition, 2 diodes use to evaluate effect of diodes of CW circuit. They showed that output voltage is different by diodes. Although, they do not elucidate that output voltage depend to what parameter of diode.

In this paper, we discuss effect of diode parameter to select element consisting circuit. Moreover, elements of CW circuit is not just diode, capacitor consists it too. Therefore, effect of parameter of capacitor is evaluated. In other hand, the sensor consists antenna and CW circuit. Effect of parameter of antenna is evaluated too. Resistance of material affect output signal if antenna receive high frequency wave. Effect of




(a).Distance between human and antenna is 0 cm.




(b).Distance between human and antenna is 200 cm.

Fig. 3. 3D plot of Capacitance of capacitor and reverse current of diode, output voltage of sensor

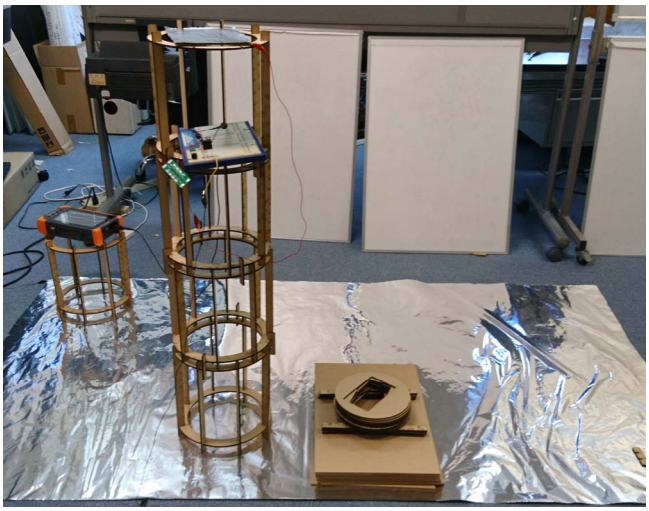


Fig. 4. Experimental setup

material of antenna is evaluated while 50Hz or 60Hz is low frequency. In addition, the more antenna area is large, the more output voltage is higher caused by coupling of antenna and noise source. However, the sensor detects human using output voltage difference due to presence of human. Therefore, effect of antenna size is evaluated.

## III. Elements of Circuit

### A. Experimental Design

In the first experiment, we evaluated the parameters of the CW circuit. The forward voltage, reverse current and total capacitance are evaluated for the diode in CW circuit, as well as capacitance for the capacitor. Eight types of diodes used in this experiment are shown in TABLE I . Capacitance of the capacitor were 1 pF, 100 pF, 0.01 μF and 10 μF. The Output voltages, (J1) in Fig.2, were measured by changing these values when the distance between the antenna and a person is 0 cm and 200 cm.

In this experiment, the antenna(AE1) was made of copper and the size was 15 cm × 20 cm. The antenna placed at 1 meter from floor. The number of steps of CW circuit was fixed at eight.

### B. Result

In case that distance between person and antenna is 0 cm, test for no correlation was applied between the output voltage and each parameter of the diode. The result of correlation coefficient were 0.128 for forward voltage, -0.747 for reverse current, -0.273 for total capacitance. The P values of them were 0.604, 0.033 and 0.514, respectively. Therefore, we can conclude that the output voltage is correlated to reverse current.

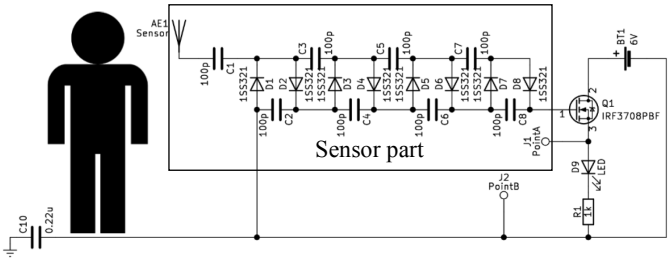



Fig. 5. Sensor circuit used in experiment

Fig.3 shows 3D plots of output voltage, reverse current of a diode, and capacitance of a capacitor. Distance between antenna and person is 0 cm in Fig.3.a and it is 200 cm in Fig.3.b. In these figures, output voltage is less than 1 V when the reverse current of a diode is more than 6 μA. CW circuit boosts AC signal by capacitor charge and discharge due to rectification of diode. Capacitor does not take enough charge due to leak current when reverse bias if using high reverse current diode.About capacitance of a capacitor, output voltage gets higher along smaller capacitance. The output voltage is maximized when the capacitance is 100 pF, although the output voltage gets lower when the capacitance is 1 pF, which is considered to be too small to charge the current. Therefore, we conclude that a feasible diode is the one with around 6 μA of its reverse current and a feasible capacitor with around 100 pF capacitance.

## IV. Material of Antenna

### A. Experimental Design

Next, we evaluated the material of antenna. Antenna and human body is might coupling to building if building is made of rebar. Steady effect is advisable in experimental. Metal foil was matted on floor as common GND and it connect to earth for that. In addition, Antenna placed high 1m from floor and human climbed a wooden platform high 60 mm to reduce effect of rebar. Improved experiment environment is shown in fig.4.

Fig.5 shows circuit for experiment. Sensor part consists antenna and CW circuit without battery. The number of steps in CW circuit was fixed at eight and size of antenna(AE1) was 15 cm × 20 cm as show in fig.5. Current of CW circuit is low. In case of using as sensor, sensor turning on FET assumes. Although, gate of FET should not is measured by oscilloscope gate of FET is high impedance. Output of source follower as output of sensor was measured for that. It was voltage between point A and B in fig.5. Oscilloscope does not affect output because impedance convert low by source follower. Elements of CW circuit were 1SS321 diode and 100 pF capacitor from result of section.3. The antenna was made of copper and aluminium because them resistance is small and processing is easy. Distance between antenna and person was 0 cm and 100

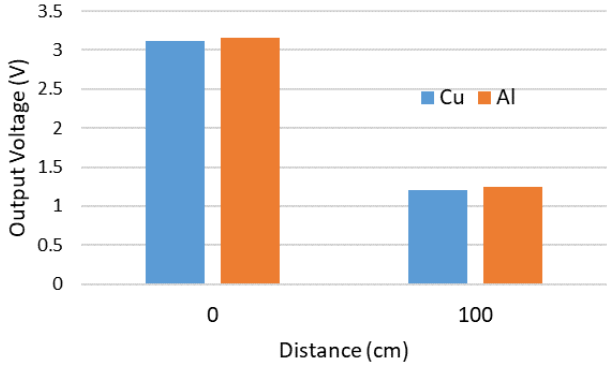



Fig. 6. Output voltage using copper antenna and aluminium antenna

cm.

### B. Result

Each output voltage is shown fig.6. In case of copper antenna, output voltage is 3.12 V when distance between antenna and human is 0 cm and 1.2 V when distance between antenna and human is 100 cm. In case of aluminium antenna, output voltage is 3.16 V when distance between antenna and human is 0 cm and 1.24 V when distance between antenna and human is 100 cm. Voltage difference for material is 0.04 V. Therefore, sensor is not effect of material of antenna. Material of antenna is not important.

## V. Size of Antenna

### A. Experimental Design

Next, we evaluated the size of the antenna. Fig.4 shows the experimental environment and Fig.5 shows the experiment circuit was same as section 4. The antenna was made of aluminium, and the size of antenna was varied by 5 cm × 7.5 cm, 7.5 cm × 10 cm, 10 cm × 15 cm, 15 cm × 20 cm, 20 cm × 30 cm, 30 cm × 40 cm, 40 cm × 60 cm, 60 cm × 80 cm, and 80 cm × 120 cm. The output voltage was measured when the distance between the antenna and a person was 0 cm and 100 cm.

### B. Result

The output voltage of each size are shown in Fig.6. In case of distance is 0 cm and 100 cm, the output voltage gets higher while the antenna gets larger. However, on the larger size of antenna, the difference of output voltage between the presenting and not presenting a person gets minor. In case that the size of antenna is more than 60 cm ×80 cm, output voltage on not presenting a person gets more than the one of presenting a person.

Larger output difference between presenting and not presenting a person is desirable as a sensor, as well as smaller size. Thus, the output difference and sensor coverage are trade-off. From the result, we conclude that the feasible size of the antenna is between 30 cm × 40 cm and 40 cm × 60 cm, whose output differences are 0.76 V and 0.12 V.

## VI. Conclusion

In this paper, we explored suitable parameters for a human detection sensor using electromagnetic noise. We evaluated parameters of diode and capacitance of the CW circuit and material and size of the antenna by output signal.

From the results, reverse current of the diodes is demanded to be less than 6 μA for the sensor. For the capacitors, around 100 pF capacity is suitable because it maximizes the difference of output voltage between presenting and not presenting a person.

For the material of antenna, copper and aluminum were tested. Output voltage between them is not so different. However, about the size, the larger antenna gives larger output voltage while getting smaller voltage difference between presenting and not presenting a person. Thus, around 30 cm × 40 cm antenna is expected to be suitable.

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