Measurement of electrostatically induced voltages in two metal boxes by using spark gap and electromagnetic wave sensor

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***Abstract*—Electrostatically induced voltages are generated in metal boxes when a charged human body moves near metal boxes with the openings. The induced voltages cause occasionally a malfunction and a failure of the electronic equipment. When a human body walks in an office using an air conditioner, the human body is electrified. The charged voltage of the human body exceeds occasionally 10 kV. On the other hand, a microelectronic device in an electronic equipment malfunctions at 10 V level or less. Hence, when the charged body such as a charged human body moves near metal boxes, the high induced voltages are generated in metal boxes. In the experiments, two metal boxes such as the boxes of electronic equipment are used. The induced voltages generated in two metal boxes are measured by using the induction electrodes accompanied with a spark gap and an electromagnetic wave sensor, and electrostatic voltmeters. The results will help to consider the electrostatic problem and the preventive measures of electronic equipment by a moving charged body.**

I. Introduction

Electronic equipment malfunctions by an electrostatically induced voltage generated in a metal box of the equipment [1-22]. An electronic device in the electronic equipment malfunctions or causes a failure by the occurrence of induced voltages of 10 V level when a charged human body moves near the electronic equipment. The voltage of the charged human body becomes occasionally 10 kV or more in an office. When such charged body moves near a metal box of the electronic equipment, the high induced voltage appears occasionally in the metal box.

The measurement of induced voltages in partially opened metal boxes is not easy without an electrical connection when a charged body moves near the metal boxes. The reason is that such electrical connection between a charged object and a measuring instrument disturb the condition of an electrical field in the metal boxes. One of best measuring methods of the induced voltages in the metal boxes is a use of a measuring method without the electrical connection. In the high voltage engineers, the voltage measurement using an electrical spark gap is frequently performed. In this study, a non-contact measuring method of induced voltages in the metal boxes is performed by using a spark gap and an electromagnetic wave sensor. Thus, the measurement of induced voltages in two metal boxes is performed.

Next fruits on the topic of the induced voltage were published by using a spark gap and of the EMI locator of an electromagnetic wave sensor, and an electrostatic voltmeter, *etc*. (1) The measured result shows that the potential difference for a piece of foil grounded in a metal box is approximately 80% larger than that for both foils ungrounded in the metal box [23]. The potential difference decreases linearly by increasing the logarithm of the distance between the charged body and the front of the metal box. (2) The induced voltage increases up to 1.6 times when the area of induction electrode in a metal box is 10 times ($100cm^2$) larger than that of $10cm^2$, and the induced voltage doesn't change so far as the area of an ungrounded metal foil is not changed [24]. (3) The induced voltage of 3 kV is generated in an ungrounded metal box when a charged body of 10 kV moves near the ungrounded metal box [25]. (4) It is clear that the polarity of the induced potential difference of the object contained in the metal box changes by moving a charged body in the vicinity of the box [26]. (5) The induced voltage generated in the metal box is independent of the volume of the metal boxes (the depth of the boxes) [27]. (6) When a ratio of the width of the shielding conductors to that of the opening of the metal box increases, the induced voltage generated in the metal box decreases [28]. (7) When a charged body moves away from a metal box, the value of the induced voltage of the metal box is -3 times greater than the voltage of a moving charged body [29]. (8) the percentage ratios of the induced voltage of the metal box to the voltage of the charged body are 56% for the measurement and 69% to 78% for the calculations, at a distance of 10 mm between the charged body and the metal box [30]. (9) The induced voltages and the electric charges increase as the facing area between the metal box and the charged body increases [31]. (10) The induced voltages of -0.42 times of the voltages of the charged body are generated in the metal box when a charged body moves away from the metal box [32]. (11) For a metal box resembling a vertical A4 size notebook (laptop) computer, the induced voltage when the charged body moves away the metal box is -4 times greater than the voltage of the charged body when the body approaches the metal box [33]. These fruits were obtained for one metal box when a charged body moves near the metal box.

The measurement of induced voltages in two metal boxes was not performed though some experiments of one metal box were performed. There are some metal boxes of the electronic equipment like desktop computers *etc*. in an office. The measurement of induced voltages in two metal boxes is necessary to consider a real electrostatic problem and its preventive measures. How high induced voltage is generated in two metal boxes when a charged body moves the front of the metal boxes? A solution of the electrostatic problem is required. In the experiments, the induced voltages in two metal boxes are measured by using two spark gaps and two electromagnetic wave sensors when a distance between two metal box is changed. The results will be helpful to solve such electrostatic problem and consider its preventive measures of electronic equipment.

II. Experimental Setup and Method

Fig. 1 shows the experimental setup. The setup represents a situation that a charged body like a charged human body moves near two partially opened metal boxes. The charged body consists of copper tapes and a styrene foam body. A whole part of the metal body of the charged body is connected to a DC high voltage power supply. The charged body puts on a transporting stage and moves automatically by the velocity of approximately 0.47 m/s. The dimensions of charged body are 1.8 m in height, 0.55 m in width, and 0.2 m in depth.

The two metal (aluminum) boxes represent metal boxes of electronic equipment. The two metal boxes have an opening in front and are grounded (earth). The two metal boxes put on an acrylic table of 1 m in height. The fronts of two metal boxes coincide with the fronts of an acrylic table. The distance *D* between two metal boxes is changed by changing the position of metal box A. The dimensions of two metal boxes are 0.2 m in height, 0.35 m in width, and 0.4 m in depth.

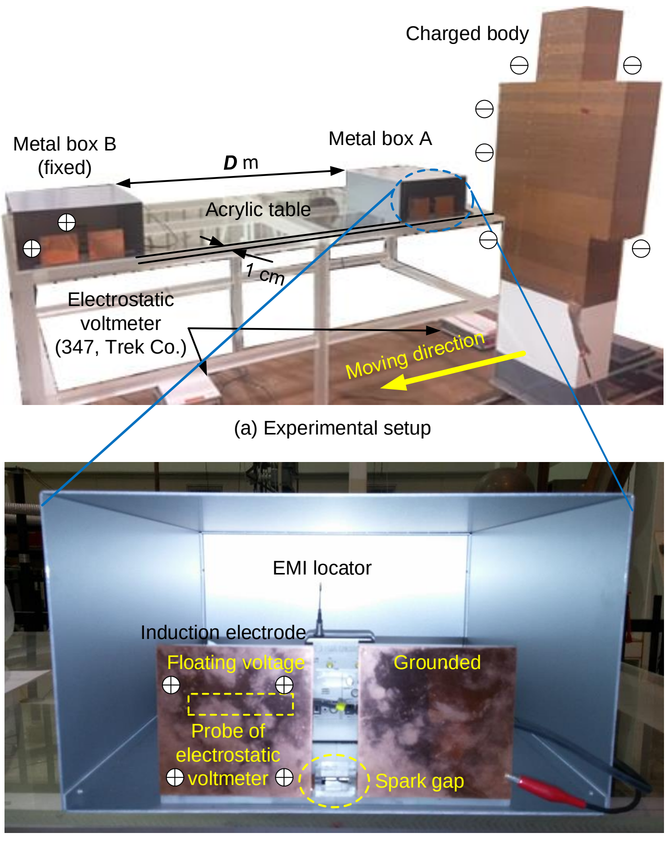

Fig. 1. Arrangement of experimental setup.

Each induction electrode puts on the base of the metal box A and the metal box B (see Fig. 1a). The induction electrode consists of a spark gap and two metal (copper) plates (see Fig. 1b). A right-side metal plate for each induction electrode is grounded. The voltage of a left-side metal plate of the induction electrode become a floating potential (voltage) because the left-side metal plate is not grounded. A probe of the electrostatic voltmeter is arranged on the back of the left-side metal plate of the induction electrode. Thus, the induced voltage of the induction electrode is also measured by the electrostatic voltmeter of 347 of Trek Co. The dimensions of a metal plate of the induction electrode are 0.1 m in height and 0.1 m in width (0.01 m^2), and 0.1 mm in thickness. The distance between the front of the induction electrode and the front of a metal box is 1 cm. When a potential difference between two metal plates exceeds a sparking voltage (Paschen voltage), a spark discharge occurs in the spark gap. The averaged sparking voltages of three measurements for 30 μm of each induction electrode are 422 V in the metal box A and 427 V in the metal box B. The sparking voltages for each induction electrode of two metal boxes are measured by the use of a DC high voltage power supply. The electromagnetic wave generated by the occurrence of the spark discharge in the spark gap is detected by the EMI locator of an electromagnetic wave sensor. The distance between the front of each metal box and each EMI locator is 0.1 m.

The experiments are performed as follows.

A) The distance *D* between two metal boxes is adjusted. The left-side of the metal box A is parallel to the right-side of the metal box B.

B) Each left-side metal plate of the induction electrode is discharged by a touch with a ground rod.

C) The charged body moves the front of two metal box after floating potential of the induction electrode is checked by the electrostatic voltmeter.

D) If an alarm of the EMI locator does not sound, the voltage of the charged body increases.

E) The charged body moves after the increase of voltage of the body.

The steps from B) to E) of experiments are repeated until the alarm of the EMI locator sounds. The voltage of the charged body for which the alarm of the EMI locator sounds is measured by three measurements. The distance *D* between two metal boxes is changed from 0.01 m to 1m. The experiments are performed under the condition of 6 ◦C and 50% R.H of the winter season.

III. Experimental Results

Fig. 2a shows the induced voltages of each induction electrode in the metal box A and the metal box B when a charged body of 900 V moves the front of two metal boxes for the distance *D* of 0.01 m. The experimental result shows the induced voltages in two metal boxes when an alarm of the EMI locator does not sound. When a charged body approaches the front of a metal plate (floating voltage) of the induction electrode in a metal box, the induced voltage in the metal box increases. When the induced voltage in a metal box becomes the peak value, a right-side of the charged body faces the metal plate of floating voltage of the induction electrode in the metal box. The negative peak induced voltages are -408 V for the metal box A and -440 V for the metal box B.

Fig. 2b shows the induced voltages of each induction electrode in the metal box A and the metal box B when a charged body of 1000 V moves the front of two metal boxes for the distance *D* of 0.01 m. The experimental result shows the induced voltages in two metal boxes when an alarm of the EMI locator sounds. The negative induced voltage is changed immediately when an alarm of the EMI locator sounds by the occurrence of a spark discharge in the spark gap. The induced voltage in the metal box A has a negative peak voltage and a positive peak voltage when a charged body moves the front of two metal boxes. The induced voltage in the metal box B has a negative peak voltage when a charged body moves the front of two metal boxes. The induced voltage is changed to a positive voltage after a negative peak induced voltage occurs by the occurrence of a spark discharge in the spark gap.

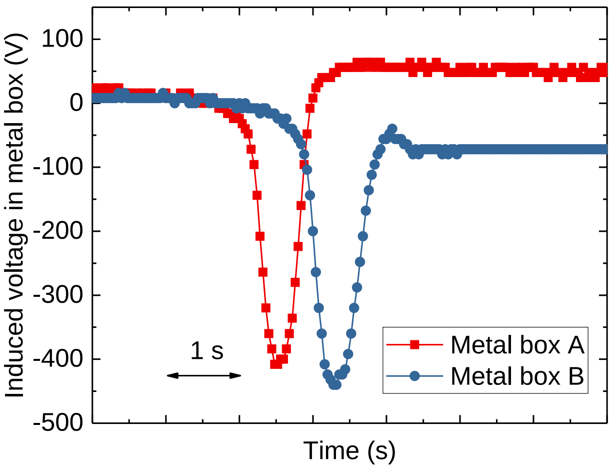

Fig. 2a. Induced voltages of induction electrode in two metal boxes for distance *D* of 0.01 m when charged body of -900 V moves the front of two metal boxes. A spark discharge of induction electrode does not occur (Alarm of EMI locator does not sound).

Fig. 3a shows the induced voltages of each induction electrode in two metal boxes for the distance *D* of 1 m when a charged body of -900 V moves the front of two metal boxes. The experimental result shows the induced voltages in two metal boxes when an alarm of the EMI locator does not sound. When we compare the experimental result in the distance *D* of 1 m with that in the distance *D* of 0.01 m, the time between negative peak induced voltages of two metal boxes increases as the distance *D* increases. The negative peak induced voltages are -376 V for the metal box A and -440 V for the metal box B.

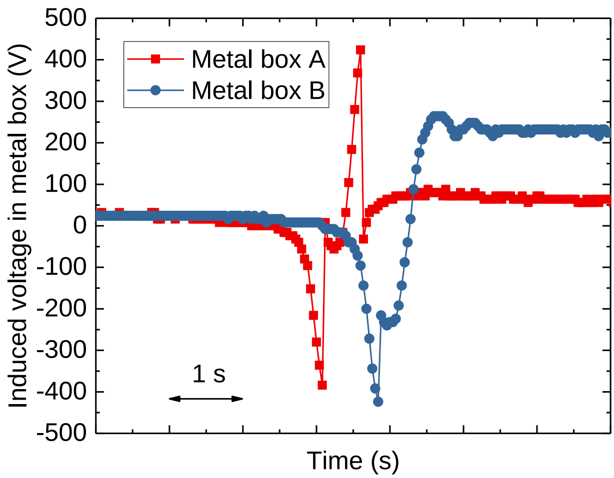

Fig. 2b. Induced voltages of induction electrode in two metal boxes for distance *D* of 0.01 m when charged body of -1000 V moves the front of two metal boxes. Alarm of EMI locator sounds.

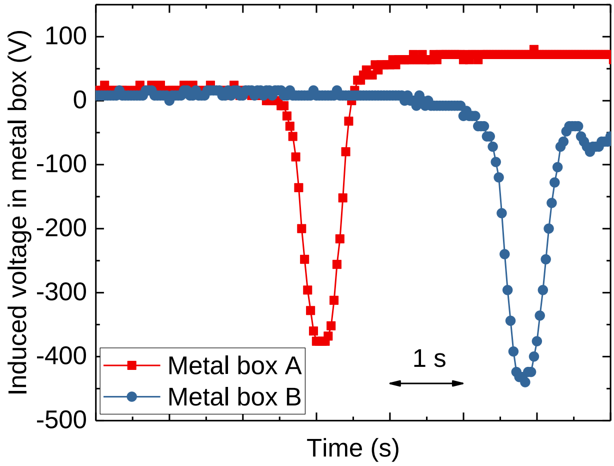

Fig. 3a. Induced voltages of induction electrode in two metal boxes for distance *D* of 1 m when charged body of -900 V moves the front of two metal boxes. Alarm of EMI locator does not sound.

Fig. 3b shows the induced voltages of each induction electrode in two metal boxes for the distance *D* of 1 m when a charged body of -1000 V moves the front of two metal boxes. The experimental result shows the induced voltage in two metal boxes when an alarm of the EMI locator sounds. The induced voltage in the metal box A has a negative peak voltage and a positive peak voltage when a charged body moves the front of two metal boxes. The spark discharge occurs at the negative peak induced voltage for the metal box B when a charged body moves the front of two metal boxes. The positive induced voltage appears after an alarm of the EMI locator sounds by the occurrence of the spark discharge in the sparking gap.

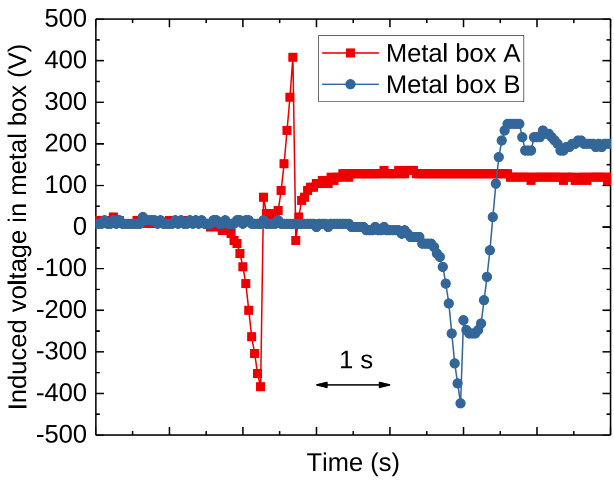

Fig. 3b. Induced voltages of induction electrode in two metal boxes for distance *D* of 1 m when charged body of -1000 V moves the front of two metal boxes. Alarm of EMI locator sounds.

IV. Discussions and Conclusions

Fig. 4 shows the percentages of the induced voltages (Paschen voltage) in two metal boxes against the voltage of a charged body. The percentages are obtained by the use of a spark gap of the induction electrode and the EMI locator in two metal boxes. The results in Fig. 4 show the relation between the percentages of the induced voltage in two metal boxes and the distance *D* between two metal boxes. The results show that the percentages are independent of the distance *D* between two metal boxes. The percentages of the induced voltages in two metal boxes are 42% to 43% of a charged body. The reason is that the distance between a charged body and the front of two metal boxes is not changed.

In the experimental study, the induced voltages in two metal boxes are measured by using spark gaps of the induction electrodes and the EMI locators, and two electrostatic voltmeters. The result will be helpful to prevent a malfunction and a failure of electronic equipment when a charged body moves near the electronic equipment. The topic is also important from the view point of the biomedical systems & emerging technologies [34-45].

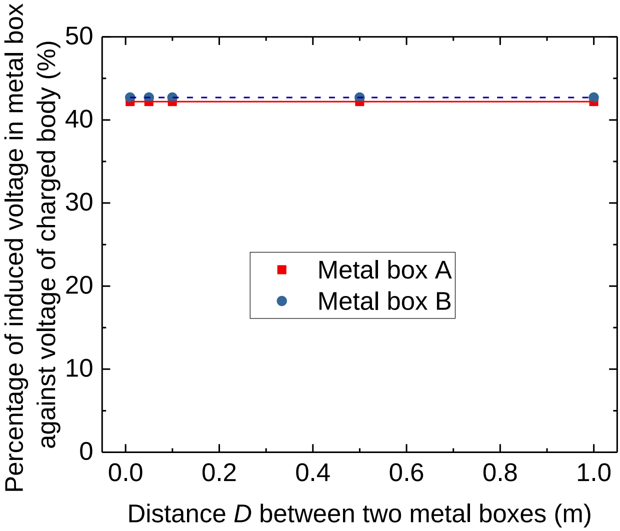

Fig. 4. Relation between percentage of induced voltage in metal box against voltage of charged body by induction electrode and EMI locator, and distance *D* between two metal boxes.

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