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Analysis of the Charge Exchange Between the Human Body and Ground: Evaluation of "Earthing" From an Electrical Perspective

Kent Chamberlin PhD [a,*], Wayne Smith PhD [b], Christopher Chirgwin BSEE [c], Seshank Appasani BSEE [c], Paul Rioux BSEE [c]

[a] *Professor, Department of Electrical and Computer Engineering, University of New Hampshire, Durham, NH*
[b] *Senior Lecturer, Department of Electrical and Computer Engineering, University of New Hampshire, Durham, NH*
[c] *Student, Department of Electrical and Computer Engineering, University of New Hampshire, Durham, NH*

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Abstract

Objective: The purpose of this study was to investigate "earthing" from an electrical perspective through measurement and analysis of the naturally occurring electron flow between the human body or a control and ground as this relates to the magnitude of the charge exchange, the relationship between the charge exchange and body functions (respiration and heart rate), and the detection of other information that might be contained in the charge exchange.

Methods: Sensitive, low-noise instrumentation was designed and fabricated to measure low-level current flow at low frequencies. This instrumentation was used to record current flow between human subjects or a control and ground, and these measurements were performed approximately 40 times under varied circumstances. The results of these measurements were analyzed to determine if information was contained in the current exchange.

Results: The currents flowing between the human body and ground were small (nanoamperes), and they correlated with subject motion. There did not appear to be any information contained in this exchange except for information about subject motion.

Conclusions: This study showed that currents flow between the environment (earth) and a grounded human body; however, these currents are small (nanoamperes) and do not appear to contain information other than information about subject motion.

Introduction

There have been numerous publications in the last decade claiming that health benefits can be realized by maintaining an electrical connection between the

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* Corresponding author at: Department of Electrical and Computer Engineering, Kingsbury Hall, Durham, NH 03824. Tel.: +1 603 862 3766; fax: +1 603 862 1832.

E-mail address: Kent.chamberlin@unh.edu (K. Chamberlin).

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human body and ground [eg, [1–11]]. This connection is referred to in the lay literature as *grounding* or *earthing*.[12] The claims suggest that whereas premodern man was almost always in contact with the ground, modern man is typically insulated from the ground (ie, use insulated shoes, sleep on insulated beds, work on carpeting or other forms of electrical insulation) and, therefore, this change has resulted in diminished health.

It is recognized that electric charges (units of coulombs [C]) can build up on an insulated human body, thus increasing its potential (volts).[13] Charge buildup is proportional to the voltage on a body, and the proportionality constant is given by the capacitance. The capacitance of a human body is approximately 100 pF,[14] where the units of Farads are Coulombs/volt. If there is an electrical path to ground, the body will discharge to ground and its potential will go to zero. The rate at which the charges flow is described by electrical current, with units of amperes which equal 1 C/s.

Although numerous articles relating to earthing have been published, little information about the electrical nature of earthing appears to be available. The clinical impact of grounding the human body is documented; but even the most basic information about grounding currents, such as their magnitudes, is not given.

It is suggested in several of the sources that some of the benefits of earthing result from information transmitted through ground currents. For example, one sources states:

> "And just like a battery in a car that keeps the motor running and the wheels turning, so, too, do the rhythmic pulsations of natural energy flowing through and emanating from the surface of the Earth keep the biological machinery of global life running in rhythm and balance.…"

Another quote from the same source states that "… electric rhythms comparable to those measured at the Earth's surface" were a necessary factor in maintaining health.

Although most references to the information contained in grounding currents are vague, one specific type of information targeted in this study relates to Schumann resonances.[15] Schumann resonances are created in the resonant cavity formed between the earth and ionosphere, excited by lightening; and they exist worldwide at around 8 Hz along with harmonics of that frequency. There are articles addressing the impact that Schumann resonances can have on humans,[16,17] and there are claims by a manufacturer of earthing equipment that "Earthing Sheets Connect Us to the Schumann Resonance of The Earth."[18] Consequently, examining the measured grounding currents for artifacts of Schumann resonance seemed to be appropriate.

These claims in the lay literature and in advertising that information transfer is an important mechanism in Earthing prompted analyses of Earthing currents for information content. The purpose of this study was to investigate "earthing" from an electrical perspective through measurement and analysis of the naturally occurring electron flow between the human body or a control and ground as this relates to the magnitude of the charge exchange, the relationship between the charge exchange and body functions (respiration and heart rate), and the detection of other information that might be contained in the charge exchange.

Consistent with the purpose of this study, the hypothesis being tested is that the currents between a human subject and ground can be measured and that those currents contain information that can be recovered, including physiological parameters such as heart rate and respiration.

Methods

This work is an extension of the previous types of work performed by the authors [eg, [19,20]] and in the University of New Hampshire (UNH) Department of Electrical & Computer Engineering. To perform the measurements relating to this study, the electronic circuit described below was electrically inserted between the human subject and ground. That circuit measured the charge flow (current) and provided an interface to a computer so that the charge flow could be logged and analyzed. The schematic diagram for the circuit used to collect the charge flow data is shown in Fig 1. So as to not impact the charge flow process, the input impedance for this circuit with respect to ground is near zero; and the circuit provides an output voltage that is linearly proportional to the current flowing through the circuit. As seen in the schematic diagram of Fig 1, the circuit uses OP-07 and LM-324 precision operational amplifiers; and these amplifiers were chosen primarily because they generate very low noise. For the circuit used in this study, that noise was found to be less than 1 nA (10^{-9} A), which was deemed to be an acceptable value for this application. It should be noted that the circuit was designed to operate on batteries so that human subjects would not

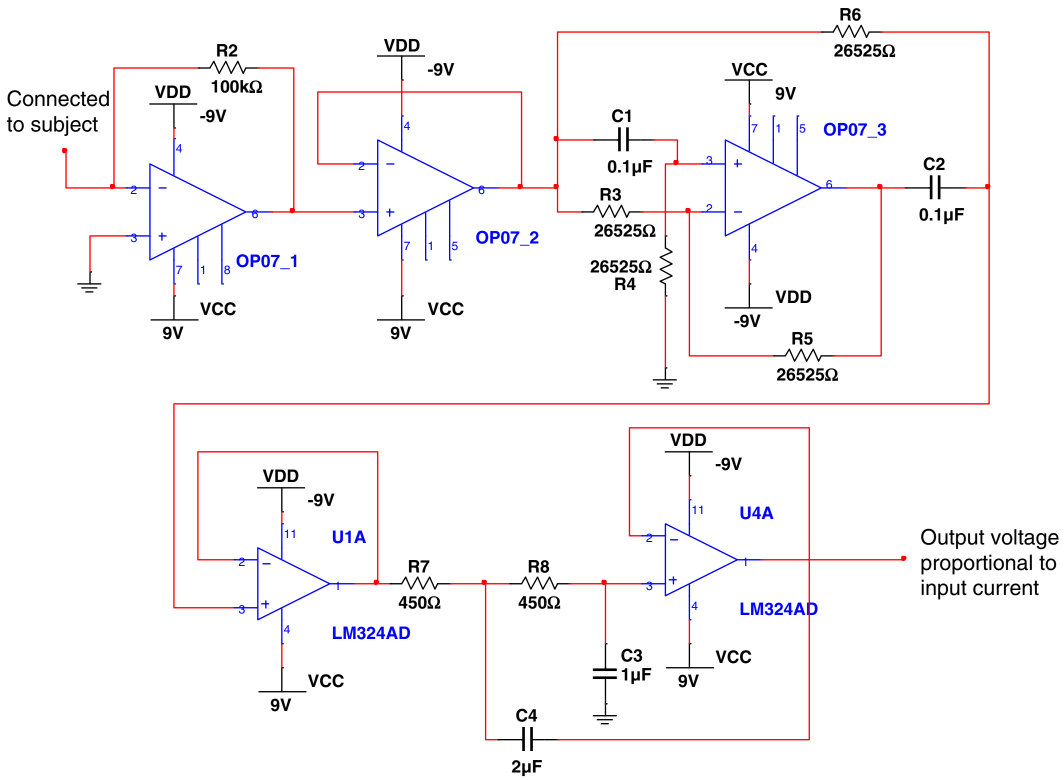

Fig 1. Schematic diagram of circuit to measure current flow.

be exposed to potential hazards associated with high-voltage circuits.

A common problem associated with measuring low-frequency bioelectric fields (eg, electroencephalogram, electrocardiogram, mechanomyogram) is interference from 60-Hz power. This interference is generally much stronger than the biosignals being measured, and it can mask those signals and saturate the equipment being used to perform the measurements. To minimize this interference, notch filters are generally used[21] in instrumentation amplifiers, and these filters permit all frequencies, except those close to 60 Hz, to pass through unattenuated. The output stage of the circuit shown in Fig 1 includes a 60-Hz notch filter that was tested and shown to be operating correctly.

Measurements of the type reported here are typically carried out using an analog sensor that is connected to a computer through an analog-to-digital converter (ADC). The ADC converts the voltage (analog) being measured into a binary (digital) format so that it can be read, stored, and analyzed by the computer. For the study reported here, the analog signal produced by the circuit of Fig 1 was converted to a digital format by a National Instruments NI-DAQ 6009, 16-bit ADC. The ADC was controlled by a personal computer running the data acquisition software LabVIEW.

For all of the measurements reported here, the sampling frequency was set to 500 Hz; and that frequency was chosen with the assumption that the frequencies contained in the current exchange would be very low, dominated by the large time constant ($t = 1/R$[resistance]C[capacitance]) imposed by the human subject capacitance and skin resistance.[22] In other words, the circuit comprised of the human body capacitance and skin resistance acts like a low-pass filter, which will impose an upper limit on the frequencies that can pass through the circuit. Because of this, it is highly unlikely that frequencies above a few tens of hertz will exist on body-connected grounding currents.

Because the analog data from the circuit of Fig 1 are sampled at a 500-Hz rate, a 250-Hz low-pass filter was designed into the circuit of Fig 1 in addition to the 60-Hz notch filter. The low-pass filter is required to satisfy the Nyquist sampling criterion,[23] which states that the signal being sampled must not contain frequencies higher than one-half the sampling rate to avoid errors due to aliasing.

The calibration curve for the measurement circuitry is shown in Fig 2, where linear response is evident, and the degree of noise which is indicated by the width of the trace. That noise is less than a nanoampere, and the nonzero offset seen in the plot was removed in the analysis process.

The frequency response of the circuit was evaluated by sweeping the frequency of the input current over the frequency range of interest and recording the amplitude variation of the output voltage. This test showed that the 60-Hz notch filter and the 250-Hz low-pass filter were working correctly and that the response of the circuit was linear over the frequency range except at the notch filter location.

A number of companies provide products that are designed to provide an electrical path between a person and ground. For example, some companies offer shoes with noninsulating soles, whereas others sell conducting desk pads and wrist straps to maintain a body at ground potential. There are also conducting bed sheets to ground people while they sleep. The electrical ground connection for these products is typically the ground terminal from a standard wall outlet, although actual ground rods can also be used. For all of the measurements reported here, the ground reference used was the ground terminal of a standard wall outlet.

The measurements reported here were obtained using conducting bed sheets that were obtained from the manufacturer.[24] These particular sheets were made conductive through the sparse use of silver thread. To perform the measurements, the ground wire was not connected directly to the wall-outlet ground, as would be the case for normal operation. Rather, the ground wire was connected to the input of the measurement circuit (denoted *connected to subject* in Fig 1). This was electrically equivalent to connecting the ground wire to the outlet ground because the circuit input impedance with respect to ground is nearly zero (ie, the input to the measurement circuit is at ground potential).

The measurements were carried out in a UNH Electrical Engineering laboratory and in student dorm rooms involving 3 men aged 22 and 23 years and ranging in weight from 140 to 210 lb. The participants were students, and the experimental protocol was approved by the UNH Institutional Review Board.[25] Because the students performing the study served as the subjects in the study, no participant recruitment was necessary and no consent form was required.

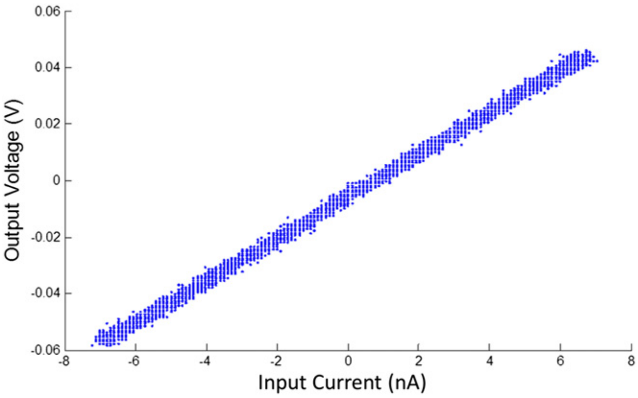

Fig 2. Input/output characteristics for circuit of Fig 1.

The measurement setup in the laboratory is pictured in Fig 3, where the subject is in contact with a conducting sheet that is connected to ground through the instrumentation described. In addition to collecting data on a human subject, a control was also used for all of the measurements taken. In the initial measurements, that control was simply an unoccupied conducting sheet, although in subsequent tests, a foil-covered dummy was used as pictured in Fig 4. The assumption was that the foil on the dummy would give it the same degree of capacitance and exposure to electromagnetic fields as a human and thus would serve as a better control than an empty sheet. However, the results showed insignificant difference between the 2 types of controls.

To determine if heart rate or respiration information was present on the grounding currents, those physiological parameters were collected in a subset of the measurements. A standard, 3-electrode system was used for both measurements. For the heart rate measurement (electrocardiogram), the positive electrode was placed at the heart base, the negative electrode was placed at the heart apex, and the ground electrode was placed on the right ankle. To measure respiration (intercostal electromyogram), the positive and negative electrodes were placed a few inches apart on the right side of the subject's chest; and the ground electrode was placed on the right ankle.

Separate measurements were performed to collect the data that would be used to test for correlation between heart rate and grounding currents, and respiration and grounding currents. In the first case, measurements were made to simultaneously collect heart rate and grounding-current data; and in the second case, respiration and grounding-current data were collected simultaneously. Thus, each of these measurements produced 2 separate files: (1) heart rate or respiration vs time and (2) grounding currents vs time. The correlation between the data contained in those files was determined using a Matlab script.

Statistics and Data Analysis

To determine the characteristics of the current exchange between the human subjects and ground, fundamental statistical analyses, frequency analyses, and correlation analyses were performed on the data.

Fig 3. Human subject on conducting sheet that is connected to ground through monitoring circuit.

The statistical analyses determined the mean and standard deviation of data sets, as well as their distribution functions. Those distribution functions were determined by calculating the number of times data points occurred within particular intervals, and scaled values of those numbers were plotted against the data value (ie, scaled number of occurrences vs current).

To determine whether information was present in the current exchange, the measured time-domain data sets were transformed into the frequency domain using 2 different Fourier techniques. What was being sought in these analyses was the existence of predominant frequencies that might indicate nonrandomness (ie, information) in the exchange. The frequency analysis of the data was performed using 2 different scales: one using a standard discrete Fourier transform to provide results from 0 to 250 Hz and the other using a numerical Fourier transform to create a detailed spectrum between 0 and 10 Hz. This detailed spectrum was created using the algorithm below, and it was used specifically to see if there were any indications of Schumann resonance frequencies in the data:

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt \approx \sum_{i=1}^{N} f(t_i)e^{j\omega t_i}\Delta t$$

This equation is an algorithm used to transform N time-domain samples into the frequency domain for any specified radian frequency ω.

The significance of using Eq. (1) is that it enables frequency to be varied continuously, whereas the discrete Fourier transform provides information only at discrete frequencies.

It is possible to extract usable information from a waveform when the information is obscured by noise. In such a case, that information would not be evident through traditional spectral analysis. However, the obscured information can sometimes be extracted if characteristics about the information are known a priori. Specifically, cross-correlating noisy measured data with a data set having the known characteristics

Fig 4. Measurement configuration with human subject and foil-covered dummy.

can reveal whether the known characteristics exist in the noisy data. For the measured ground-current data, cross-correlation techniques were used to determine whether information about heart rate or respiration was present.

Results

The time-domain data (ie, measured current flow vs time) collected in this study are unremarkable, as they appear to be zero-mean noise. The readily discernible difference between data collected with the human subject and the control is that the noise on the human subject is considerably larger and it is punctuated with occasional impulsive noise. Observations made during the measurements showed that the impulsive noise occurred whenever the subject moved. It is assumed that the movement caused a static charge buildup that was discharged through the grounded measurement circuitry.

Fig 5 shows the distribution function of current for both the control (left) and human subject (right) for a typical measurement session. All of the data collected for this study exhibited similar characteristics to those seen in Fig 5. As seen in the figure, the distribution function plotted for the control is what would be expected for band-limited noise, whereas the human-subject data cover a wider range of current values, are bimodal, and are asymmetric.

The autocorrelation provided the same results as would be expected for band-limited noise, a rapidly decaying impulse centered at $\tau = 0$, and as such did not reveal any information content. Further, as seen in the spectrum in Fig 6, no pronounced signal is evident at any frequency. The same is true of the 0- to 250-Hz spectrum; both spectra appear to be the spectra of noise.

Because current flow was seen to correspond to human subject motion, a final analysis was performed to determine if heartbeat or respiration information could be recovered from the data. Using grounding currents to detect those physiological parameters was considered to be a possibility, as there are some motion artifacts associated with heart rate and respiration. The frequency spectra indicate that such information is not strong in the data; otherwise, there would be components evident at around 0.2 Hz (respiration) and 1 Hz (heart). However, even signals that might be too weak to show up in the frequency domain data might still be sufficiently strong to be extracted using correlative techniques. To check for this possibility, the cross-correlation was calculated between the charge-flow data and heartbeat, and the charge flow data and respiration. For both of these calculations, the maximum correlation coefficient calculated was near zero, indicating that those physiological parameters cannot be extracted from the current-flow data.

Discussion

As seen in Fig 5, the distribution function for current for a human subject is bimodal and asymmetric. An explanation for this distribution is that there is a pronounced charge-discharge cycle associated with subject motion and that the motion-induced charging is considerably greater than the background noise. Consequently, the bimodal peaks are likely created

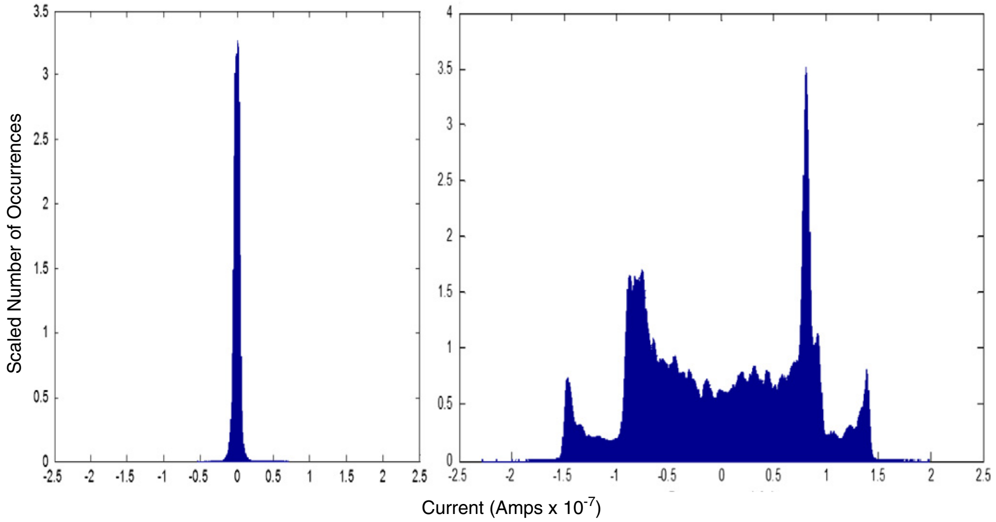

Fig 5. Relative probability distribution of current flow for control and human subject.

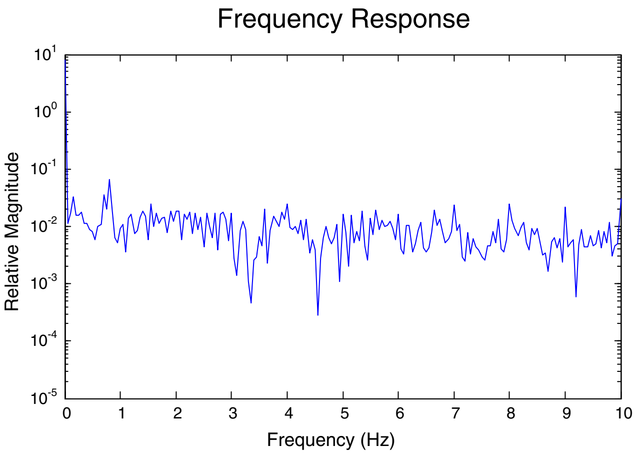

Fig 6. High-resolution frequency spectrum of charge exchange between human subject and ground.

by the motion-induced charge/discharge cycles. The asymmetry in those peaks is assumed to be caused by differences in the manner in which the body charges and discharges. Specifically, the body loses charge quickly with motion; and that charge is transferred to the surrounding bed clothing. To return to an electrically neutral state, an equal amount of charge must flow back from the ground; and that return flow will be slower because of the high resistance of the bed clothing. Whereas the charge inflow/outflow distribution is not symmetric, the net current flow for the sessions was found to be nearly zero.

The hypothesis being tested in this study postulates that grounding currents are measureable, and that turns out to be the case. The currents are small; and they have the characteristics of zero-mean noise, punctuated by impulsive noise that occurs when the subject being measured moves. Because the impulsive noise on the ground current correlates with subject motion, it does contain information, which is another aspect of the hypothesis. However, information relating to subject motion appears to be the only information that can be derived from the grounding currents. Thus, the findings of this study do not provide any validation for the health benefits of earthing resulting from an information exchange between a human subject and ground.

Because subject motion can be determined from grounding currents, those currents might prove useful as a movement sensor. A motion detector can be constructed using circuitry similar to the circuitry used in the study reported here, and its output would indicate the number of movements over time. Such a measurement is relevant to quality of sleep, and it would be far easier to implement and at a lower cost than video systems that are used to assess motion during sleep.[26,27] In fact, the cost for the sensor would likely be sufficiently low so that it would be affordable for home use as well as institutional use. Using existing technology, the sensor could be wirelessly connected to computing devices, such as a smartphone, where new applications could be written to analyze the motion for specific patterns. For example, it is quite conceivable that particular sleep-related disorders, such as restless legs[28] syndrome, can be identified through the analysis of grounding currents.

Limitations

Perhaps the most identifiable limitation to this study is that measurements were performed on only 3 individuals. The original intent for the study was to study a greater number of participants, although increasing the participant pool was later considered to be unnecessary because of the similarity in the measured data for the 3 individuals studied. Specifically, there was no discernable difference in the magnitude or characteristics of currents collected on individuals of disparate size (140 lb compared to 210 lb). To verify that the fundamental magnitude and nature of grounding currents do not vary measurably from person to person, with the exception of motion artifacts, additional measurements can be performed.

The measurements reported were collected at the UNH in the winter and early spring, when the humidity was relatively low in buildings. That lower humidity allowed for a greater charge buildup than would have occurred in a high-humidity environment. The relationship between charge buildup and humidity explains why static-electric shocks are more prevalent in the winter than the summer, where the greater humidity season provides a lower impedance path to ground when compared with dry air. Using this reasoning, it would be expected that grounding currents would become smaller as humidity increases; and this aspect of earthing was not explored in this study.

Although the analyses of data did not show the presence of information, such as Schumann resonances, this does not necessarily mean that such information is not present, as it may simply be lower than the ambient/instrumentation noise level. For example, it has been shown that Schumann resonances can be masked in high-noise environments.[29] Consequently, the failure of this study to identify information in grounding current does not rule out the possibility that it may exist.

Conclusions

The data collected in this study show that charges flow between the human body and ground if a ground path exists. That charge flow is small, with a magnitude of less than 10 nA after the ground path has been established. The currents correlate with human subject motion; and no other information appears to be present, such as heartbeat, respiration, or other earth-body communication.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

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