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Signal Scavenging For Passive Monitoring In Eldercare Technology

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Abstract—**Signal scavenging is analogous to energy scavenging: seemingly ubiquitous energy in the environs provides the signal for usage as a personnel sensor. Such energy can be used to detect motion, and most importantly falls. Stray signals can be detected in aluminum foil as voltage differences between touched foil (say by hand) compared to that untouched. Spectrum analysis shows the stray electromagnetic noise signal consists substantially of 60 Hz and its harmonics. Also the signal intensity for both touched and untouched monotonically increases with foil area. While personnel monitors find utility in many areas including security, personnel control and activity detection, we believe these putative sensors to be useful in inobtrusive monitoring of elders to provide them with increased independence at a critical time in their lives.**

I. Introduction

Energy scavenging recognizes that energy exists in the environment in a wide array of forms. A common example is the self winding watch that uses wrist motion to provide energy for operation. Other common examples include the use of solar, wind and ocean energy; these sources can and do provide large amounts of energy, as is well known.

The sensor engineer is familiar with the nuisance of 60 Hz and other stray electromagnetic noise that limits the operation of the sensor, and may even require extensive effort to overcome. We propose using this noise as a ubiquitous source of signal. We use the term signal scavenging to describe the use of that noise as a source of energy for signal detection. In particular we are interested in using the fact that the noise level read from a sample of aluminum foil increases when touched by a person.

The motivation for this study is to use signal scavenging as a means to monitor the elderly for motion and falls. There are many applications for unobtrusively monitoring the elderly [1]. Inobtrusive means the individual has given their explicit permission for this monitoring and aware if it, the individual need take no action to effect the operation or performance of the system and the individual's privacy is not violated. Studies in our group indicate that older adults were concerned about falls and that they perceived technologies that monitor activity levels and sleep patterns as useful. The older adults emphasized the need for non-obtrusive systems [2]. A monitoring system using these foils is passive and will increase the effectiveness of caregivers by providing access to the motion of the individual.

The elderly are particularly vulnerable to falls. Falls are dangerous and require immediate assistance; there are anecdotes of those who have fallen and waited undiscovered for hours or even a day or more. In addition, predilection to conditions such as falls, and changes in daily patterns may indicate impending health problems [3]. Inobtrusive sensing technology can provide alerts. More generally, there is evidence that technology can provide early detection of changes in the health status of the elderly [4], and we believe that a monitoring system with careful attention to the data can provide those benefits.

Monitoring and fall detection is also important for those with Alzheimer's, since it has been known for a while that falls also are associated with cognitive dysfunction [5]. Some of the published literature indicates that approximately 60% of older people with cognitive impairment fall annually, that's approximately twice that of older people without cognitive impairment. The increased odds of falling in older adults with cognitive impairment put them at increased risk for major injury such as fracture and head trauma [6]. A more recent study shows that women with mild cognitive impairment have a greater number of fall risk factors compared to older women without mild cognitive impairment [7], and these women had significantly reduced balance and limb coordination.

In this paper we characterize the signal scavenged from aluminum foil for the purpose of developing an inobtrusive sensor system for the elderly. We characterize the voltages detected upon activating (touching) the foil and non-activating. We further characterize the noise by the low frequency spectra appearance the dependence of the detected voltage on foil area.

II. Methods

We undertook a series of experiments to identify the properties of the noise signals that we read from aluminum foils. For these experiments we used Hewlett Packard 54602B laboratory oscilloscope, with 150 MHz bandwidth, two channels and millivolt sensitivity. A Tektronix 4 Channel Oscilloscope (TDS3054B) was used for the spectrum analysis.

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The foils were laid out and connected to the oscilloscope through wires glued to the foil using MCG-8331 MG Chemicals Silver Conductive Epoxy. The glue has high electrical conductivity, although no direct measures of conductivity were made. Figure 1 shows a typical square sample of aluminum foil with glued wires (which connect to the oscilloscope).

Figure 1 Aluminum foil covered by vinyl (for protection and ease of use) with leads glued in place.

We measured electrical energy from foils with and without contact with a person. We refer to activated foils as those touched or in contact with a person. In case of comparisons the contact was applied the same way. In many experiments we stepped on the foil and read the activation, in others we touched by hand, and still others it was most convenient to apply hand pressure on the foil covered with transparent sheet of plastic. Non-activated, inactivated, or non touch foil data was read without touching or stepping on the foil.

III. Results

We compare a single measure of activated and non-activated foil in the plot shown in figure 2. The activated signal level is at hundreds of millivolts compared to the non-activated, at 10s of millivolts. As will be shown and discussed below we also measured the activated and non-activated average voltages of 10.77 mv and 2.33 mv, and the RMS voltages at 53.99 mv and 5.25 mv. These comparisons help characterize the voltages indicating that there is not much of DC component. Secondly, variations in the 'scope display due to variations in touching can produce noticeable differences in the various voltage readings indicating a temporary variation in DC component.

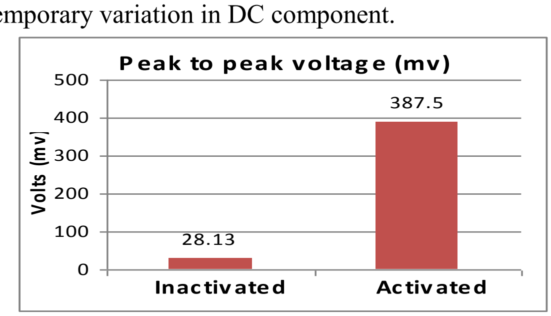

Figure 2 shows the peak to peak voltage read when the foil is momentarily touched.

The foil acts as an antenna that when touched acquires a substantial increase in ambient electrical energy. The oscilloscope shows (Fig 3) the signal variation with and without activation. To obtain reasonably repeatable result we touched the foil in similar ways each time. The manner of touching produced different wave forms in comparing differences between activated and non-activated. Clearly a motivation of this study is to learn to tame the signal source.

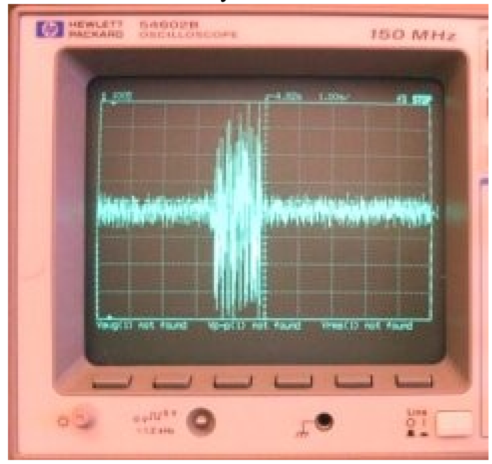

Figure 3 Electrical energy added to the foil as a result of a person touching (activating) the foil. The smaller noisy portion of the trace has a level at 30mv p-p, whereas the larger activated potion is nearly half a volt.

We prove here that this electrical energy consists of stray electromagnetic energy ubiquitously available in the environment. The sources include 60 Hz power line energy, stray energy from nearby electrical or electronic equipment or appliances, radio and television station signals, and possibly other sources including wireless Personal Digital Devices. To try to identify these sources we decided to obtain the spectrum of the signal. It was most confinement to focus on the low frequency (2.5 kHz and lower) energy.

We obtained data from activated (touch) and non-activated (non-touch) foils. The data was downloaded onto an excel spread sheet and the plots shown here.

We obtained a linear display of the spectrum from dc to 1500 Hz. Shown in figure 4 is a linear display of signals obtained from non activated foil. The 60 Hz is the dominant component in this display (see table 1).

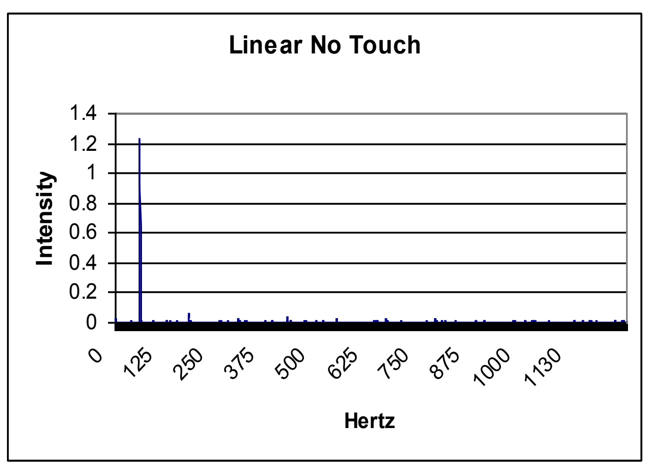

Figure 4. Display of the linear spectrum of data acquired from a foil of aluminum connected to an oscilloscope. Note the substantial spike at 60 Hz.

It is the most easily identifiable component of the data and includes the 60 Hz signal and its frequency components or harmonics.

The same data was displayed in logarithmic mode to diminish the 60 Hz component and enhance the other prominent components (Figure 5) Note the spikes of

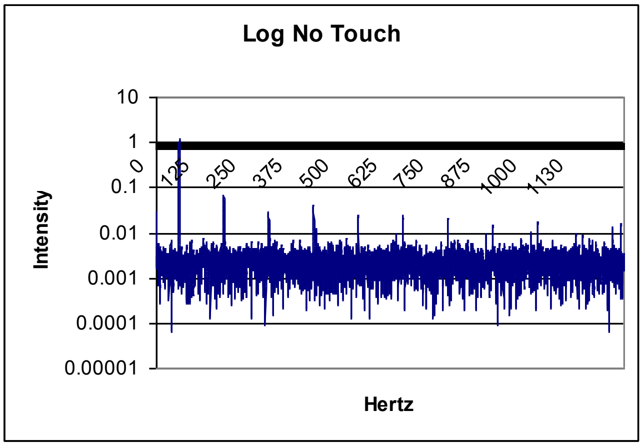

Figure 5 allows a reading of the components expressed in table 2.

components of odd harmonics of 60 Hz, and note the substantial noise levels between the spikes; these remain to be studied. Table 1 lists the frequencies and amplitudes directly read from figure 4. Beyond 900 Hz it is difficult to honestly discriminate the level of the 60 Hz components since they are approaching the level of other data spikes not readily attributable to 60 Hz components.

Table 1 Amplitude and frequency of prominence in the noise energy.

Frequency	Amplitude
60	1.226
180	0.066
300	0.029
420	0.018
540	0.022
660	0.024
780	0.021
900	0.015

The most remarkable fact here is that these are the odd harmonics of 60 Hz (1, 3, 5…). We looked carefully at the time domain signal for this spectrum, which was triangular, with 60 pulses/sec repetition rate. Riding on top of the triangular patter were small components of amplitude variation. Providing confirmation that we indeed were dealing with odd harmonics of 60 Hz

We obtained the spectrum of the noise data from 6inch square aluminum foil. We compare the activated (touched) foil to inactivated foil (no touch) to form figure 6. We see that the 60 Hz component spikes were consistently larger in the touch case compared to the no touch case. Remarkable we also see even harmonics of 60 Hz, which were suppressed in figures 4 and 5 above, indicating the statistical nature of the noise. In this case the even harmonics are substantially reduced compared to the nearest odd harmonic. Furthermore in the activated (touch) case the drop in amplitude is more pronounced than that of the inactivated case.

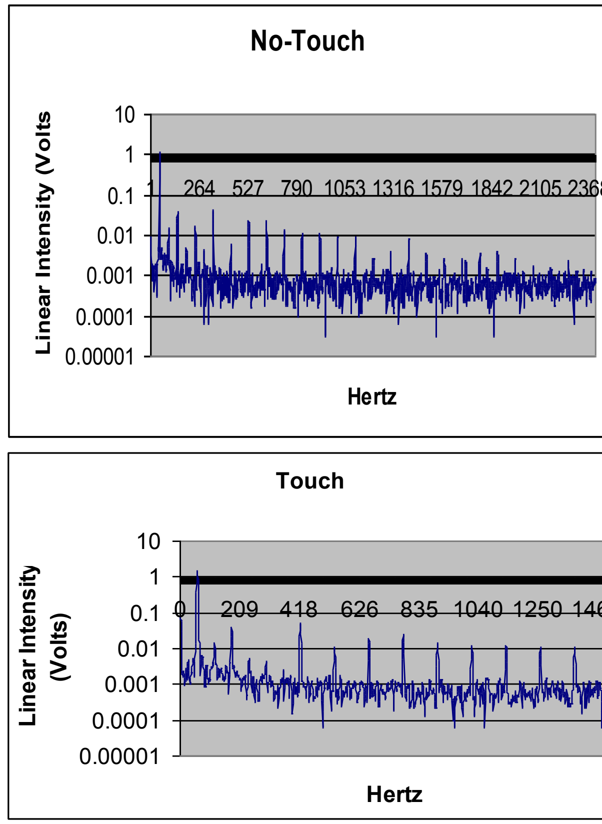

Figure 6 (upper) the log of voltage intensity for activated foil samples. Note the predominance of the odd harmonic, but the even harmonics are distinct from the background. (Lower) The inactivated foil shows a substantially lower harmonics compared to the activated foil.

It has come as a surprise to us that there does not appear too much randomness in these data. This clearly needs substantially more study. But the primary source of energy clearly comes from 60 Hz stray signals. We are so accustomed to calling noise and stray signals random, that it is surprising that the easy call of random signal cannot be yet be affirmed or denied.

Clearly for use as sensors it is important to consider the variation in size. We obtained the touch and no touch values of noise from 6 foils ranging in area from 2, 4, to 64 square inches and plot the results in Figure 7. There is clearly a separation between the activated and non-activated values. We should point out that similar data was obtained for peak to peak voltage (112 mv inactivated, and 900 mv activated). Interestingly the size of the foil is important since

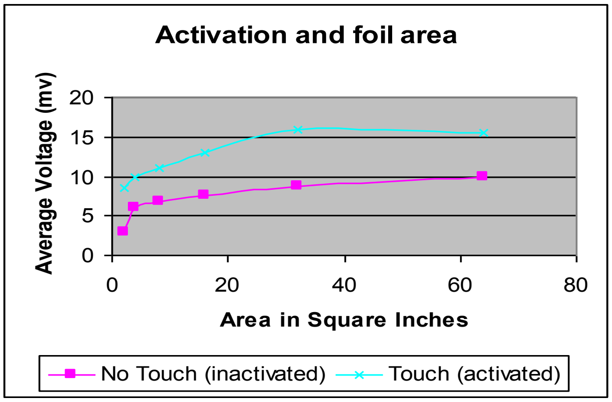

Figure 7 Comparison of activated and non-activated foils by size. The voltage monotonically increases with a linear increase in area. Here we compare the average voltage. At the smaller sizes we risked losing the signal altogether, with increasing area we reach an inflection point at around 32 sq. in. Further increase in size does not improve the signal difference.

larger provides more signal. But smaller provides more resolution. We note the maximal inflection of the activated data at 32 sq in. This point seems to be that at which the method of touch that we used did not increase the noise level appreciably, a trend the non-activated foils did not express. The foils were strips 4 inches long with the appropriate width to fill out the required area (the last though was 8” x 8”). This gives the intriguing possibility of providing improved resolution compared to the larger foils.

IV. Discussion

Signal scavenging takes advantage of stray electromagnetic energy to detect the presence of (or the touching by) personnel in a conductive foil. We used aluminum foil which is cheap and easily available. This is similar to the capacitive buttons used in electronic systems except that we do not use any energy source other than that picked up by the foil. This of course is the chief advantage in that there is no need to provide power and the foils are completely static devices.

Clearly the primary source of energy is 60 Hz stray electromagnetic energy. Furthermore the activated foils show a substantial increase in the main 60 Hz signal, which is 20 to 40 times greater than the higher harmonics of the waveform. Additionally there is some variation in the detected signal where we have seen primarily odd harmonics and other times we see both odd and reduced even harmonics. While this is an interesting insight, it does not really affect the detection of the noise since we use total noise. We continue to explore ways of improving the detection of the signal. There is some satisfaction in using as a signal source the stray energy that is the bane of most sensor engineers, namely the 60 Hz stray noise.

We have been concerned about repeatability and reliability. Are there places where this system will not work? Clearly in Europe where 50 Hz power is used, we should see those frequencies in our data; again this is not a problem for the same reason that amplitude discrepancies at various 60Hz components do not trouble us. However in those locales where no electrical energy is present or where it is far away we may not have sufficient stray noise to detect.

V. Conclusion

We have shown that it is possible to use passive foils to distinguish between activated and non-activated foils; activation means touching. We have provided low frequency characterization of the scavenged signal to be 60 Hz stray electromagnetic energy with the first 10 harmonic components providing recognizable increases in energy. Furthermore the signal strength, as expected, monotonically increases with foil area.

Future work will be to further characterize the scavenged signal and to develop sensors.

VI. Acknowledgment

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