Transforming human gait for signature signals characterization

Atika Arshad, Ahmad Fadzil Ismail, Sheroz Khan, A.H. Zahirul Alam, Rumana Tasnim, Syed Samnan Haider, Mohammed M. Shobaki and Zeeshan Shahid
Department of Electrical and Computer Engineering
International Islamic University
53100 Kuala Lumpur, Malaysia

E-mail: atikaarshad@hotmail.com

Abstract. An integrated wireless inductive sensor is reported based on a system for monitoring human movement and body size. The proposed system senses the presence of human beings using electromagnetic field by making use of basic inductive coupling approach, hence analysing the performance of human monitoring. The amalgamation of the integrated system proposed will help in providing better services to the elderly people resided in healthcare centres. The developed sensing system is of low cost, flexible, robust, and easily implantable and capable of inductive sensing through marking signature waveforms as a result of human movements.

1. Introduction
Non-contact sensor systems are an emerging technology consisting of miniaturize, low-power, and low-cost devices. This technology has the potential to have enormous impact on many aspects of signal monitoring system. An inductive coupling technique is a very reliable method for supplying power to remote inaccessible region such as biomedical implants, structure-embedded micro-sensors, or safety monitoring devices in harsh environments conditions, since inductive coupling gives higher level of power transfer efficiency when compared with target devices powered directly from solar light, thermal energy and so on. Energy harvesting using light sources restricts the working environment of electronic systems. Such systems cannot work normally in low light or dirty conditions, whereas thermal energy can be converted to electrical energy by the seebeck effect however the working environment for thermo-powered systems is also limited [1]. Also, energy harvesting using light can be practical for autonomous implantable biomedical sensors [2], but the energy harvested is in low power (µW range). However, inductive coupling from an external power source is preferred because it performs better compared to the different methodologies of energy harvesting mechanisms where the devices are powered directly from the energy source; such as piezoelectric, thermoelectric, photovoltaic, or ultrasound. Inductive coupling provides higher power...
transfer efficiency and reliable control. The power received could be in the milli-watt ranges with a reasonable distance while the transmission could be electronically controlled [3].

Several non-contact techniques for the detection of remote sensors are cited. In [4], a research was conducted using passive telemetry technology for measuring the intraocular pressure (IOP) of an eye in a continuous manner. The sensor proposed is implanted between the eyeball and the orbital bones where it can be fixed and also where it will be an easy access for surgery. The powering source system is an external coil wound around an eyeglass producing magnetic field which is magnetically coupled by the IOP sensor allowing the changes in impedance to be measured with response to variations of pressure on the sensor. The basic idea proposed in this system is to use an implanted resonant LC circuit magnetically coupled to an external coil embedded in the glasses. The capacitor of the LC resonant circuit is the pressure sensing device. The aim was to measure the resonance frequency of the sensor, which depends only on the value of its inductance and capacitance. Since the capacitance of the sensing device is related to the exerted pressure, the IOP will be obtained from the measured resonance frequency by varying the capacitance value, hence simulating for different pressures.

Recently a research showed an innovative technology to charge vehicle batteries without using the traditional method of gasoline. This novel technique is based on inductive power transfer interface (IPT) technique that allows a bi-directional and contactless power interface for the electric vehicle (EV) to be wirelessly charged or discharged by loose magnetic coupling [5].

Moreover, inductive loop sensors are currently being used to detect vehicle under a heterogeneous and less-lane-disciplined traffic [6-7] for traffic controlling and management system. These inductive loop sensors can not only detect the size of vehicles but also enables accurate counting of the number of vehicles in peak time. These types of sensor are basically embedded under the surface of the road.

Another paper [8] reports the use of wireless, passive sensor based on an inductive-capacitive resonant circuit for monitoring the growth of bacteria. The sensor is a planar, printed or photolithographically defined resonant circuit, the response of which is remotely detected by a loop antenna measuring the increase in complex permittivity of the bacteria concentration level thus indicating if a food product is safe for human consumption. The sensor comprises of an inductor-capacitor (LC) resonant circuit, which is placed within the biological medium of interest.

Furthermore the same authors proposed another practical wireless telemetric sensor for monitoring humidity levels in the packaged food [9]. The sensor developed is made of a planar inductor and capacitor printed on a paper substrate. The taste quality of the packaged food can be indirectly determined by measuring the change in the sensor’s resonant frequency, which is proportional to the environment moisture content. To monitor food quality, the sensor is embedded inside the food package by adhering it to the package’s inner wall; its response is remotely detected through a coil connected to a sensor reader. As food quality degrades due to increasing humidity inside the package, the paper substrate absorbs water vapour, changing the capacitor’s capacitance and the sensor’s resonant frequency.

Among the different sensor strategies, different groups have proposed the use of inductive-based devices, where sensing is determined by the changes in the inductance of a coil. Moreover by using the concept of the work reported in the literature this paper proposes a novel wireless inductive sensor based on a system for monitoring the signature signals of human movement and body size. The potential of the inductive device for the development of the sensor is strongly conditioned to the availability of a suitable signal conditioning circuit. One of the most used approaches is based on the measurement of the resonant frequency of an LC circuit containing the inductive sensor. In this
framework, this paper analyzes the viability of a signal conditioning circuit sensor for monitoring purpose.

This paper is organized as follows: Section II describes the system architecture. The theoretical derivations are given in Section III, while the analytical and simulation results under assumed working conditions of the system proposed are given in Section IV. Conclusion of the outcomes for the proposed system, together with some ideas for expansion of this work is at the end.

2. System Architecture

The sensor architecture for remote sensing is shown in Fig.1. The sensor is endowed with computation and communication capabilities collaborating with each other in order to transfer the information of interest from desirable sources (at places such as control room, diagnostic facilities) to intended target devices. Such target devices may be employed to humans being diagnosed. Telemetric systems such as these could be used for remote sensing online, continuous, and real time telemedicine monitoring. Such systems are beneficial not only in the detection of abrupt changes of patients’ health, but also in the assessment of the right dose at the right of medication. This type of monitoring allows patients in elderly homes to remain engaged in the normal activities of daily life while treating their complications by either staying at home or close to places and premises providing specialized medical services.

The sensor architecture is composed of three sections, as depicted in Fig.1. The general requirements at each section of this architecture are presented as follows.

![Sensor detection architecture](image)

Fig.1  Sensor detection architecture

Using non-contact sensor technology, this telemetric link consists of a sensor (conditioning circuit) at the point of signal origin which collects data about the environment showing the status of the monitored inhabitant (presence of human, presence of object, and presence of no object/human). Hence the sensor can use wireless link to collect data about the status of the inhabitant remotely and perform appropriate actions when necessary that is by sending data to the second part which is the processor. The analysis and filtration of the data into information is done by the processor which will
assist in suitable decision making; like the monitored person’s nature is checked for deviations from their “normal” behaviour. The normal behaviour is able to signify worsening conditions of elderly patient’s health. Lastly the transmitter will send the data to a computer for displaying the acquired data on a computer before a medical expert.

In this paper, a wireless inductive sensor is proposed for monitoring of human body size and movement in a closed room. The proposed sensor consists of a core-less, hollow and multi-turned coil that is capable of storing energy in its magnetic field when a current passes through its turns. The sensor is proposed to be employed under the floor of a patient’s room in such a way that a passing human brings about changes in inductance. The change in inductance produces an impedance spectrum which is detected by measuring the impedance across the terminals of the loop.

Fig.2 Circuit schematic of detection system

Fig.2 represents a given sensing system; relevant analysis is made for obtaining transfer function. The magnitude and phase of the same are plotted to be compared with similar plots obtained from PSpice simulation of the same circuit. Here $Z_L$ is the sensor inductance (with a parallel capacitance and a load). The difference between the signals $V_0$ and $V_{in}$ is analyzed versus the inductance of the sensor $Z_L$. The transfer function of the proposed circuit is derived as

$$
H(s) = \frac{V_0}{V_{in}} = \frac{C_1 C_2 C_3}{s^3 (LC_2 C_3^2 + LC_3 C_2^3) + s(C_2 C_3^2 C_1 + C_2^2 C_3^3 + C_3^2 C_2^3)}
$$

(1)

The results can ultimately be used for identification of gaps and proximity of humans moving around the coil under question.
3. Results
The circuit in Fig.2 is applied to the characterization of the status of the inhabitant of human using inductive coils. The analysis of the proposed system will allow the demonstration of the ability of this simple circuit for the high-sensitivity detection of the inductive changes from integrated inductive coils.

The derived transfer function in equation (1) is plotted to show that it peaks up to a certain frequency. This frequency depends upon the inductive element in the circuit. The sensor portion of the system consists of an LC circuit. The LC circuit has an inductor with a fixed value of capacitor. In the specific sensor proposed, in this investigation the magnet wire will be assumed to be non-magnetic and with no core, hence the permeability can then be said to be equal to that of free space. The change of inductance is measured for three inductance value 100mH, 150mH and 200mH. Fig.3 indicates the graph obtained analytically by plotting magnitudes and the phase of the transfer function as a function of frequencies reflecting equation (1), whereas Fig.4 presents the simulation results. There is similarity between the analytical derivations and the simulated results obtained; both are on accordance to each other.

Moreover from the results obtained, it is obvious that the distinctive impedance waveforms can be represented as the change in human movement for real time biomedical application.

![Fig.3 Magnitude and phase response for the resonance frequency plots for the change in inductance via analytical derivation](image-url)
4. Conclusion
This work builds a model of the inductive loops on signal acquisition to monitor and analyse different postures of human body under varied condition (change in inductance value). This analysis has allowed demonstration of the ability of a very simple circuit for the high-sensitivity detection of the inductive changes from integrated coils. The resulting signals are very susceptible to ambient noise sources, and decontamination can be carried out by adaptive filtering methods. To develop such adaptive filter, robustness and an intelligent filtering system is required for obtaining a well-defined detection signal which will be an additional room for this research work.

References

[1]. Yen Kheng Tan, “Sustainable Energy Harvesting Technologies – Past, Present and Future”, Published by InTech, Chapter 2, p.25, Dec 2011.

[2]. S. Ayazian, V.A. Akhavan, E.Soenen and A. Hassibi, “A Photovoltaic-Driven and Energy-Autonomous CMOS Implantable Sensor”, IEEE Transactions On Biomedical Circuits And Systems, Vol. 6, No. 4, pp 337-343, August 2012.

[3]. Young-Sik Seo, Minh Quoc Nguyen, Zachariah Hughes, Smitha Rao and J.-C. Chiao, “Wireless Power Transfer by Inductive Coupling for Implantable Batteryless Stimulators”, International Microwave Symposium, Montreal, Canada, June 17-22, 2012.

[4]. S. Lizon-Martinez, R. Giannetti, J.L. Rodriguez-Marrero and B. Tellini, “Design of a System for Continuous Intraocular Pressure Monitoring,” IEEE Transactions on Instrumentation and Measurement, Vol. 54, No. 4, August 2005
[5]. U.K. Madawala, D.J. Thrimawithana, “A Bidirectional Inductive Power Interface for Electric Vehicles in V2G Systems,” IEEE Transactions on Industrial Electronics, 58(10), pp. 4789-4796, October, 2011.

[6]. S.S.M. Ali, B. George, L. Vanajakshi and J. Venkatraman, “A Multiple Inductive Loop Vehicle Detection System for Heterogeneous and Lane-Less Traffic”, IEEE Transactions on Instrumentation and Measurement, May, 2012, 61(5), pp.1353-1361.

[7]. S.S.M. Ali, B. George, and L. Vanajakshi, “A magnetically coupled inductive loop sensing system for less-lane disciplined traffic”, IEEE International Instrumentation on Measurement Technology Conference (I2MTC), May, 2012, pp. 827- 832.

[8]. K. G. Ong, J. S. Bitler, C. A. Grimes, L. G. Puckett and L. G. Bachas, “Remote query resonant circuit sensors for monitoring of bacteria growth: application to food quality control,” Sensors 2002, 2, 219-232.

[9]. Ee Lim Tan, Wen Ni Ng, Ranyuan Shao, Brandon D. Pereles and Keat Ghee Ong, “A wireless, passive sensor for quantifying packaged food quality,” Sensors 2007, 7, 1747-1756