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Detection of person presence and its activity in the bathtub

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Detection of person presence and its activity in the bathtub

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Abstract. A practical application of a bioimpedance technique for a detection of a bathing person is presented in the paper. It addresses the possibility of supervising people in the bathtub without voiding of their intimacy. The measurement system installed in a fiber-glass or a plastic bathtub is able to detect a presence of the bathing person, to estimate its activity and thus to detect potentially dangerous events. In the paper a principle of measurement, working prototype and measurements are presented. The proposed method can be useful for supporting and supervising bathing of elders, partially disabled or people with some health state risk during the bath and living alone.

1. Introduction

The bathroom is a very important place in every house for hygiene and maintaining of the health. It is also the place where one can expect maintenance of his (her) intimacy. However, due to the tasks performed and the type of furniture it can be also one of the most dangerous places in the house. Wet floor and hard furniture might be dangerous especially for elders with some mobility dysfunctions. There are reports from social care employees of elders that could not manage to leave the bathtub itself and thus were kept staying in the water for prolonged period (eg. a whole night). There are also reports of sudden when bathing [3]. In such situations the supervision of bathing person without voiding of their intimacy could be invaluable assistance. The bioimpedance technique seems to be a well suited for a detection of biological cells presence in solutions. Detection of a person presence in the bathtub can be thus regarded as a problem of detection of living cells in the water.

In the frequency range between 1 kHz and 10 MHz impedance of a water (with salts and detergents) exposes mainly resistive character. In contradiction, for the living cells there is a characteristic magnitude of the impedance drop at certain frequency which is related to polarization phenomena. In this frequency range a characteristic phase angle shift is also present.

Presence of the measuring electrodes and associated connecting wires introduce stray capacitances. They limit the resistive range to below 1 MHz. When a human body is immersed in a water character (frequency dependence) of the measured impedance is changed. It is known that living cells exhibit, aside the resistive, capacitive properties. Moreover, electrical properties of the living cells are also dispersive characteristic impedance change around specific frequency and it is associated with a significant change of phase angle. The principle of operation of a

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developed system is based on measuring the impedance using set of electrodes placed at the bottom of the bathtub. Changes of the impedance modulus measured for the selected frequency are monitored and used for evaluating the bathing person activity. Variance of modulus value is utilized to estimate movement of the bathing person.

2. Materials and Methods

The concept of bathing person monitoring relies on the impedance measurement. Thus, the plastic (or acrylic) bathtub is equipped with three electrodes placed on the bottom of the bathtub. Each electrode is compound one, i.e. it contains both, the current and voltage parts. The impedance is measured between selected pair of the compound electrodes, giving two independent measurements.

2.1. Sensitivity of measurements

Assume bounded domain with two regions: one of the background conductivity of σ_1 and another one of a perturbation conductivity of σ_2. Following the Gesselovitz sensitivity relationship we obtain [5]:

$$\Delta Z = \int_V -\Delta\sigma \frac{\delta\phi(\sigma)}{I_{1-2}} \cdot \frac{\Delta\Psi(\sigma + \Delta\sigma)}{I_{3-4}} dv$$

where the V denotes the volume of considered domain Ω , the σ and $\Delta\sigma$ are the conductivity, and conductivity change of the domain respectively, ϕ is the potential within Ω caused by current I_{1-2} issued between ports $1-2$ and ψ is the hypothetical potential within Ω caused by hypothetical current I_{3-4} applied between ports 1 and 2.

In general conductivity is non-uniform and it depends on spatial conductivity distribution in relation to the measurement ports and in case of dispersive materials on the frequency.

In the considered problem - detection of presence of the human in the bath - the measured impedance change depends on the frequency, conductivity of the bathing fluid and position of the person in relation to the measurement electrodes.

Considering the frequency range of $2kHz - 100kHz$ the bathing fluid exhibits constant, frequency independent and real (no imaginary part) conductivity. For the human body the modulus of the impedance is strongly frequency-dependent value in this frequency range. It is related to the dispersion phenomena, mainly involved by a presence of the living cells (cell membranes). Thus analysing the impedance spectrum of bathing fluid it is possible to distinguish between bathtub filled only with fluid from the bath with the person immersed in it. Under certain circumstances it is possible to detect presence of bathing person by measuring constantly impedance on selected frequency.

2.2. The measurement system

The measurement system was constructed basing on AD5933 (Analog Devices Ltd) integrated circuit. The AD5933 is a complete impedance analyser including DDS with sine-table stored in ROM, output amplifier, input I/U converter and a complete digital synchronous demodulator using the 1024-bit real and imaginary register. The AD5933 is controlled by means of the IIC using ATMega32 (Atmel) microcontroller. The AD5933 utilizes a two-electrode method. It creates a major problem for using it in the considered application. In a case of the bioimpedance measurement using two-electrode method leads to false readings as the electrode impedance is included in the readings.

To meet the measurement requirements an input circuit of AD5933 has been enhanced with additional one. It utilizes Howlands voltage controlled current source, an instrumentation amplifier, additional filters and polarization circuitry [4]. However, an application of AD5933

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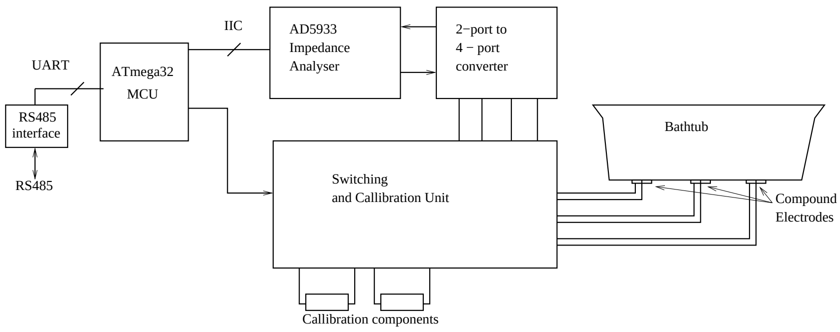

Figure 1. Block diagram of the measurement system

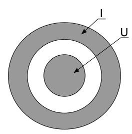

Figure 2. Measurement electrode shape

in a four-electrode technique involves a development of a calibration procedure. To improve performance of the measurement system the calibration resistors are included in the circuit. Moreover, the calibration procedure must be performed for each individual frequency, selected from the prescribed frequency table. The calibration procedure requires to determine three parameters: magnitude scale factor, offset value, and the phase correction angle. It has been developed and tested using the reference components which were integrated with the measurement circuit.

3. Results

The measurement system has been designed, and the prototype of the measurement board has been developed as it is shown in figure 3. An acrylic bathtub has been equipped with the measurement electrodes (figure 4). Electrodes are made of silver-plated brass and glued on the bottom of the bathtub. The measurement system is a part of broader one containing displays and servomotors used for bathtub filling and flushing [1, 2]. Thus, the impedance meter has serial RS485 interface for data transmission. Tests of the developed system were performed. However, instead of two frequency measurements a spectroscopic ones were utilized. A volunteer has been asked for taking the bath using the developed system. He has been asked to perform several exercises (movements) during the test. We used a casual liquid soap for bathing and in a second test we used a bathing salt. After performing the calibration the bathtub was filled with a warm tap water. Impedance of the water has been measured . When the person entered the bathtub impedance measurements have been performed again (see figure 5).

Additionally volunteer was asked to stop moving for certain period, and then to start moving. Instead os spectroscopy, such activity could be monitored using continous single frequency measurements. Exemplary result is shown in the figure 6.

During set of measurements the performance of the measurement system was checked. Usually for the same conditions the measurement error is less than 1%. A special caution must be taken when selecting frequency of the measurement signal. It appears that for a certain frequency measurement errors are greater than for other. Fortunately, a selection of an adjacent frequency (e.g. 1Hz higher) can solve the problem.

4. Conclusion

We have proposed the monitoring method of the bathing person. It is based on electrical impedance measurement without using camera. We have designed ant tested the performance of the measurement system. The information gained can be assigned to several categories e.g. no body in the bathtub, body present in the bathtub and it is moving, body present , no movement detected. Such information is used for detecting of dangerous situations when taking the bath,

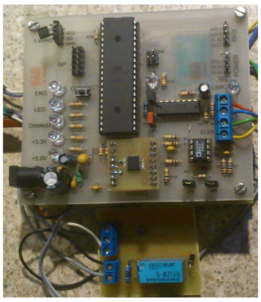

Figure 3. Prototype of the measurement system with the self-calibration

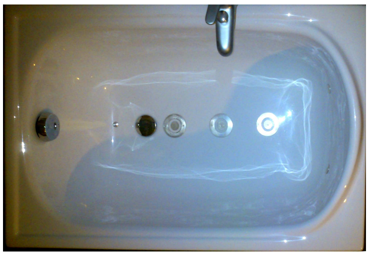

Figure 4. Modified bathtub

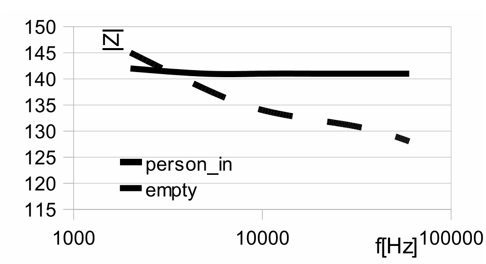

Figure 5. Comparison of the bath impedance with and without person

Figure 6. Continous monitoring of person activity - modulus of the impedance measured at 30kHz in 1s time interval. Until 7 sec volunteer was relaxed, after started to move

and in connection to other systems (alarms, water flushing system, etc) can improve safety of the bathing person without violating her/his intimacy and privacy.

5. Acknowledgements

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