Using Human Body for Data Transmission and Power Harvesting

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ABSTRACT

The contribution concentrates on the area of the possibilities and design of a soldier's personal warning equipment communicating with UGS which uses the human body both for data transmission and its own feeding. When performing operations in built-up areas, soldiers are exposed to a high degree of danger because of unclear situation and complicated character of the town agglomeration. In addition, built-up areas bring with them endangering from roofs and windows of the surrounding buildings as well as from cellars or underground objects. To lessen the risk of danger, it is possible to use UGS whose models are being miniaturized down to the form of Smart-Dust Technology and make possible to inform the soldier about the possible imminent danger in time. The warning information about the danger must be, in many cases, handed over to the soldier without any unmasking effects so that no backlighting of a display or acoustic tone will betray their presence. At the same time, it is not possible to hand over the required information about a possible danger to the soldier at the expense of a lessening of their watchfulness.
The contribution describes a design of UGS which can be used in built-up areas and in places where classic UGS are too large or their installation is complicated. The following part of the contribution deals with the possibilities of utilization of human thermal and kinetic potential for feeding of electronic circuits with low power demand. Then the possibilities of the utilization of the conductivity of the human body as a data bus for the communication between the individual electronic segments for data exchange and control are described in the contribution. The design, implementation and the results reached in the designing of soldier's personal warning equipment for UGS which uses human body for its own feeding and data transmission are also described in the contribution. The contribution is completed with measured data and photographs of the designed soldier's warning equipment. The conclusion deals with the development trends in this area.

1. INTRODUCTION

The urban environment has unique characteristics, making humanitarian or military operations difficult and dangerous. Cities possess great numbers of noncombatants, are dense with vital infrastructures and important sociopolitical institutions, and are usually cluttered three-dimensional spaces that pose significant logistical and navigational challenges. Urban terrain, being a man-made environment, is composed of angular forms, the like of which occurs only rarely in non-urban terrain. [1]
A large city provides several planes of "urban high ground" and, in many instances, a subterranean level in addition. Sensors and communications operate less reliably and at reduced power in urban terrain. Persistent surveillance of the urban area is essential to all types of actions used to isolate an urban area and as complete as resources will allow. Surveillance of the urban area relies on either reconnaissance forces or sensors continuously observing or monitoring urban avenue of approach. Useful sensors working in urban terrain are Unattended Ground Sensors – UGS. Typical characteristic of UGS is their relatively small size and the number of UGS installations is usually limited to several tens of pieces in one protected perimeter. On the other hand it is suitable to say that the detection ranges to the violator are generally from

tens to hundreds meters; it depends on usage of the sensor particular type. Somewhat different design approach lay is substitution of one large UGS with high detection range to the violator by several tens of miniature UGS with smaller detection range. The condition of the approach - usage of many miniature UGS - must bring the required detection effect; decrease of total purchase price and also in other aspects it may not be self-purposeful. Common types of the UGS are shown in Fig.1. UGS usually consists of several dozens of autonomy working sensors and one personal monitor, on which the data from individual sensors on violation of secured area are displayed. [2-7]

Fig.1 Unattended ground sensors type examples from the left: MIS (GBR), PEGGY (CZE), Falcon Watch (USA)

2. PERSONAL AREA NETWORK

The UGS warning information about the danger must be, in many cases, handed over to the operator without any unmasking effects so that no backlighting of a display or acoustic tone will betray their presence. At the same time, it is not possible to hand over the required information about a possible danger to the operator at the expense of a lessening of their watchfulness. This might be solved by additional equipping of the operator's personal monitor with an independent vibration device which is usually used in cell phones and which would inform him discreetly about possible threat. The vibration device can then be located e.g. in shoes, in a collar or on other sensitive places of the body. The inconvenient cable between the personal monitor and external vibration device can be replaced with data communication over the human body, which means on the PAN principle.

Talking about Personal Area Network - PAN within the frame of commercial products, such as cell phones, portable computers, GPS receivers, pagers, MP3 players etc., the data communication among them settled on the use of several standardized technologies, such as for example USB metallic interface or IR, WiFi, Bluetooth type high-frequency wireless interfaces and others. Intra-body communication using the human body as the transmission medium allows wireless communication without the use of airborne radio waves. Because signals pass through human bodies, electromagnetic noise and obstacles have little influence on transmission, and the signals do not leak through the skin.

Methods for intra-body transmission can be divided into three types, as shown in fig.2:

1. *Simple circuit* - regards the human body as a conductor. Although this is a simple method, it nevertheless requires a wire outside the body.
2. *Electrostatic coupling* - connects all devices to the ground. This transmission type was used in Zimmerman's study of PANs. Electrostatic coupling does not need an external cable; however, transmission quality depends on the surrounding objects.
3. *Waveguide* - in this method, interest signal is generated by flats propagates through the body and is received by another flats. An external cable is not necessary and transmission quality is not affected by an individual's surroundings.

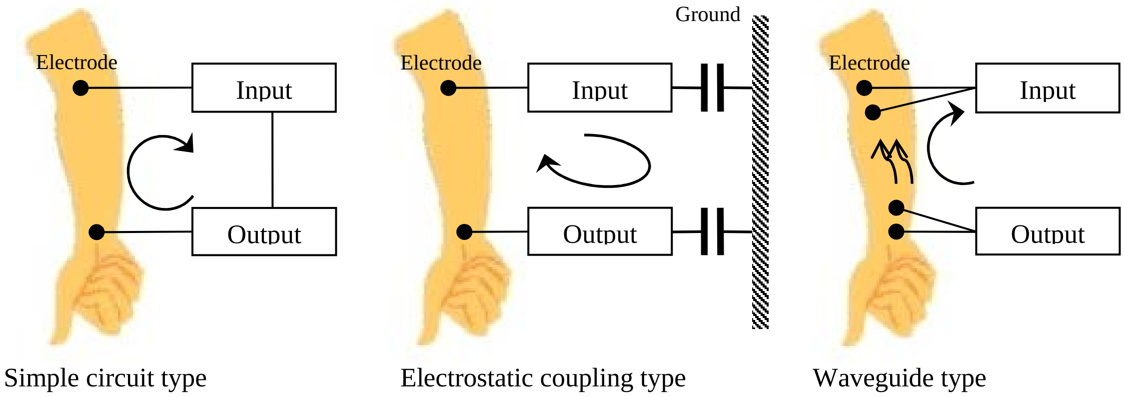


Fig.2 Three types of intra-body transmission

The transmitter electrode closest to the body has lower impedance to the body than the electrode facing toward the environment. This enables the transmitter to impose an oscillating potential on the body causing lumping electric fields on it. Similarly the impedance asymmetry of the receiver electrodes to the body and environment allow the displacement current from electric fields to be detected. Since the impedance between the receiver electrodes is nonzero, a small electric field exists between them. The transmitter capacitively couples to receiver through the body.[8-10]

As the data transfer speed between the transmitter and receiver is not required to be too high, measurement of usability of human body qualities was carried out for the data transfer in the frequency band of 1– 3.5 kHz. This frequency band was chosen mainly due to the expected usage of the programmable paging tone decoder of CMX 823 type or of the decoder using the DTMF modulation. Another reason for the use of the frequency band in the range of a few kHz is the expected use of operational amplifiers with ultra-low power input which are able to amplify and cover this frequency band without any problems. A signal from the wobbled low-frequency generator was led to a pair of mutually and outwardly insulated copper flats with the dimensions of 30 x 12mm and its ground. A similar pair of flats was used as the receiving part.

The sinusoidal signal from the generator was retuned in the frequency band of 1 – 3.5 kHz and had the signal output value set to 3V. The signal from the receiving flats was led directly to the inverting amplifier input with the input resistance of 100 kΩ and amplification of 60 dB. The transmitting and receiving flats were fastened to the upper parts of man's clothing. A spectrogram of the measured signal is shown in Fig.3.

It is clear out of this record that the maximum signal level is on the frequency of 50 Hz and its periodic multiples, which corresponds to the frequency of the mains voltage. There are also control signals of centralized ripple control of the electric supply network on the frequency of 216.6 Hz clearly visible in the spectrogram.

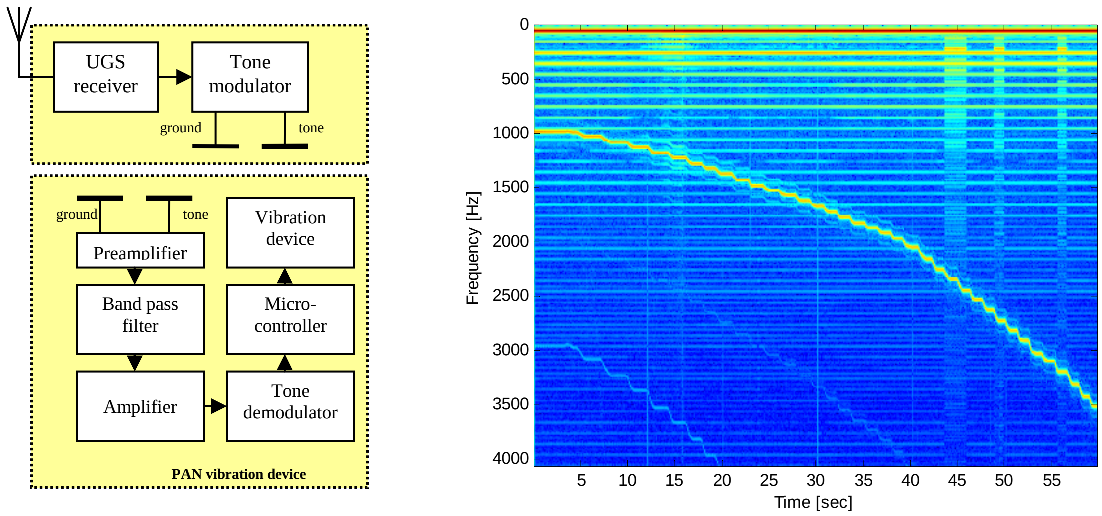
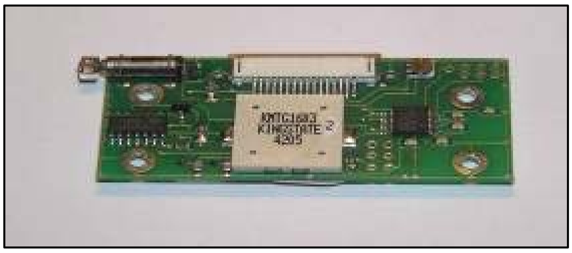


Fig.3 PAN prototype block diagram and Spectrogram of the measured signal

However, the service band of 1 – 3.5 kHz shows a constant level of transfer and there are no places with considerable attenuation present here. Besides, it was found that we reach the similar results in cases when the transmitting and receiving flats are located on different parts of the trunk or limbs. In other word, it is indifferent where in the upper clothing the operator is going to put the personal monitor and vibration device, or as the case may be, other components that communicate via a human body. A PAN prototype has been developed to demonstrate the digital exchange of data through a human body using battery-powered low-cost electronic circuitry. Layout block is shown in Fig.3. The high-frequency signals from the individual nodes are captured in the UHF band by the UGS receiver. The signals are decoded here and shown on the LCD display.
However, at the same time the decoded signals are controlling the frequency of the sine oscillator, the output voltage of which is led directly to the pair of the transmitting flats. The sine signal had to be used due to the spectral purity of the signal, because the decoder is relatively sensitive to higher harmonic components included in the square wave signal and thus, no ambiguous decoding of the modulating signal occurs. The signal from the receiving flats is led to the pre-amplifier, which provides impedance match to the connected filter of the band-pass type. The band-pass type filter has the band pass set within the range of 0.5 – 3.5 kHz which corresponds to the decoder working band. Afterwards, the second amplification stage follows, output of which is led to the input of the CM-823 type decoder. The decoded data are led through SPI interface into a control microcontroller, which controls switching of a mechanical vibrator. In addition, the assembled prototype can also be connected to the LCD display and has a control outlet for acoustic and visual indication of the received signals. Both the transmitting and receiving flats are insulated from the ambient surroundings. The used tone decoder allows direct decoding of totally 32 different frequencies and the capture time for one frequency is approximately 40msec. Thus, the used decoder allows data transfer at the speed of 15 bytes per second. As the control microcontroller has in its memory saved all the data on nodes and violation types from nodes, such transfer speed is fully sufficient because of the used index addressing. PAN vibration device prototype photograph can be found in Fig.4.



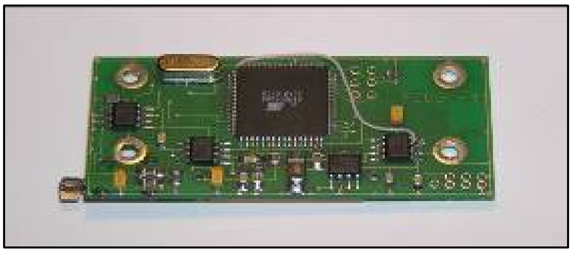


Fig.4 Picture of the PAN vibration device prototype

The operator had the UGS receiver located on a universal load-bearing vest on his back. The vibration device was located in a shoe of the operator. This location appeared to be very suitable because shoes form an integral part of the outfit and the operator does not have to think about the device location any more. Besides, a foot sole is during a walk sufficiently sensitive to the vibrations caused by the device and no undesired acoustic betraying revelation occurs. After a short training, the operator was capable of identifying clearly up to eight different alarm messages according to the type of vibration. Besides, it was verified in practice that it is possible to use for the data transfer also the frequency band in the range of dozens and hundreds of kHz, and thus to increase the data transfer speed.
The way of encoding was chosen mainly with regard to its significant robustness and resistance during data transfer even under the conditions when the operator was in a close distance from strong high-frequency or low-frequency radiation sources.

3. POWER HARVESTING

The idea of harvesting power from human motions is not new. Hand-crank generators, foot pedals, cigarette lighters, bicycles, etc. are examples of human-powered devices, but all need deliberate exertion on the part of the user to operate. The goal of parasitic power is to inconspicuously derive power from the user’s motions without deliberate action being taken. The methods and options of power harvesting have already been published in many documents and can be found e.g. in [11-20].
Vibration-powered generators are typically, although not exclusively, inertial spring and mass systems. There are the three main transduction mechanisms employed to extract energy from the system. These transduction mechanisms are:

1. *Piezoelectric* generators employ active materials that generate a charge when mechanically stressed.
2. *Electromagnetic* generators employ electromagnetic induction arising from the relative motion between a magnetic flux gradient and a conductor.
3. *Electrostatic* generators utilize the relative movement between electrically isolated charged capacitor plates to generate energy.

The practical realizations of above mentioned transduction mechanisms are commercially accessible.

However the human body and environments at different temperatures offer the opportunity for energy scavenging via heat transfer. The Carnot cycle provides the fundamental limit to the energy obtained from a temperature difference.[21]

Thermo Life® converts heat energy to electrical energy through its thermopile couples using the thermopile principle Seebeck effect. Thermo Life® is a commercial thermoelectric generator measuring 0.68cm^2 in area by 1.4 mm thickness. Comprising a dense array of Bi2Te3 thermopiles deposited onto thin film, it can generate 10 µA at 3V (6V open circuit) with only 5°C of temperature difference.

Thermo Life® generator can power low-drain biosensor electronics when in contact with the skin. These systems typically come with batteries that store extra energy produced during periods of higher ΔT so they can continue to run during warmer, less efficient ambient temperatures.

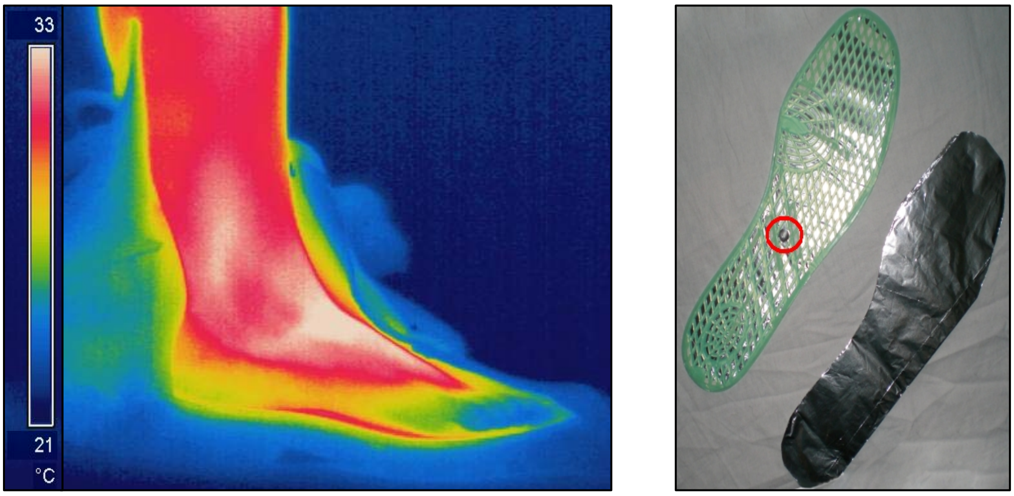


Fig.5 Thermal print of heat distribution inside the boot (left), Thermo Life® generator thermo-insole model (right)

Thermo Life® generator that is small enough to fit service boot inside was tested for usage as an option of vibration unit PAN battery recharging. The thermo-print of heat distribution inside the boot at 20°C surrounding temperature is presented in Fig. 5. The figure clearly shows sufficient temperature difference in the foot arch area. An example of thermo-insole model is in fig.5 on the right-hand side. The practical tests done with the Thermo Life® (R) generators verified the voltage output of 1.4 V and current output of 8µA per generator.

It is evident that at least three pieces of Thermo Life® generator connected in series are necessary to produce voltage output of at least 4 V.

3. CONSLUSION

Present urbanized fighting ground becomes more often the area of armed terrorist attacks. To this environment it is necessary to adapt tactic of military, humanitarian and monitoring operations, but also outfit persons, which are participants of these operations. It is presented small UGS which within unified information network cooperate in real time with the other information systems.

A practical example of PAN usage for violation indication in connection with UGS receiver is given in the paper. Problem-free transfer of service data was carried out even in cases when the operator had the UGS located near his waist or when he had just his forearm laid on it. UGS receiver modifications are just minimal. It is sufficient just to lead the impedantly separated demodulated signal to the transmitting flat. The signal level of 3V is fully sufficient for the data transfer with PAN application. Simple OOK modulation or other can be used, however then it is inevitable to use the more complicated way of data packet encoding with self-correcting feature. The way of encoding described in the paper was chosen mainly with regard to its significant robustness and resistance during data transfer even under the conditions when the operator was in a close distance from strong high-frequency or low-frequency radiation sources. The PAN vibration device is located in the operator's shoe and is fed by its own flat Li-Pol accumulator, additional charging of the accumulator has been tested using shoe insert equipped with one piece of Thermo Life® generator. The tests confirmed multiple pieces of Thermo Life® generator connected in series would be needed to recharge vibration unit PAN battery. It would be necessary to consider paying more attention to finding suitable thermo insulator materials to improve Thermo Life® generator efficiency. The most serious disadvantage for Thermo Life® generators is their elevated purchase price. Another question missing in the paper is the recharging of the built-in battery at times the operator wears other or no footwear. However, the author will publish more results of the matter.

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