Personal area network using human body properties

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Abstract: - The paper deals with the possibility of data transfer, using a human body as a transfer channel. A physically separated transmitter and receiver are located in clothes on various parts of the human body. The individual parts that perform data communication between each other are referred to as **P**ersonal **A**rea **N**etwork - PAN. This paper includes starting requirements on data communication through the human body and also actual parameters taken on the human body in the function of the transfer channel. The end of the paper describes construction of a vibration alarm device that was assembled and verified. Although this paper concentrates predominantly on military applications, the operation principle of data transfer over the human body that was used here can be directly implemented to purely civil usage.

Key-Words: - Unattended ground sensor, personal area network, human body communication

1 Introduction

Performing operations in a built-up area limits the movement, maneuvering and controlling of armed forces significantly. To protect one's own units, a dedicated communication network is often created with many inputs in the form of sensors with process units and with information which can be distributed to every soldier and commander on the battlefield. To lessen the risk of danger, it is possible to use **U**nattended **G**round **S**ensors - 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. UGS consist of a variety of sensor technologies that are packaged for deployment and perform the mission of remote target detection, location and/or recognition. Ideally, the UGS are small, low cost and robust, and are expected to last in the field for extended periods of time after deployment. They are capable of transmitting target information back to a remote operator. These devices could be used to perform various mission tasks including perimeter defense, border patrol and surveillance, target acquisition, and situation awareness. Smart packaging of UGS in addition to self-location and orientation of sensors greatly improves their performance capability for deployment. Sensor fusion capability at the device level greatly enhances the probability of detection and probability of correct identification of target over range. Sensors built within UGS are generally passive in nature and can include acoustic, seismic, magnetic and IR capability. Correlation of features from various sensor technologies greatly enhances the target-recognition capability.

The UGS 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. Unattended 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. An example of possible UGS layout of REMBASS-II type is shown on Fig. 1.

Fig.1. UGS - REMBASS-II

Communication between the individual sensors and personal monitor is mostly carried out via radio channel in VHF band in order to ensure a safe data transfer on high or densely forested ground. The personal monitor is considered a part of the outfit and the data from individual sensors on violation are shown in the form of alphanumerical symbols on the display. The personal monitor is usually equipped with an acoustic indicator and a display backlight. As mentioned above, the acoustic and visual indication might have the effect of exposure, betraying the position of the operator, especially at night and in quiet surroundings. In addition, the operator has to have the personal monitor in operation located in such a way that he could see the display. 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.

2 PAN communication channel

Talking about 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 standardised technologies, such as for example USB metallic interface or IR, WiFi, Bluetooth type high-frequency wireless interfaces and others.

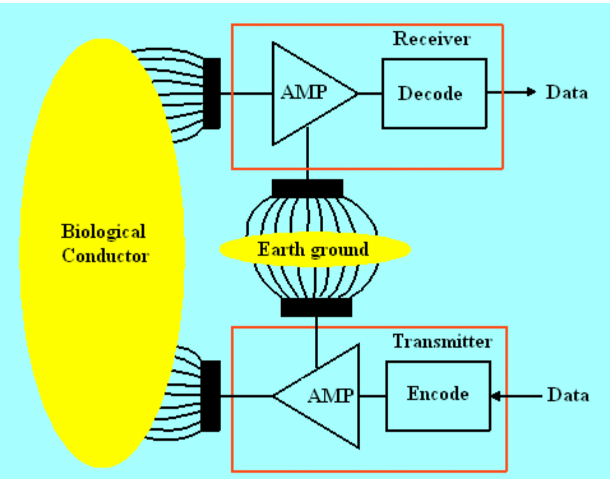

Fig.2 Block diagram of the PAN system

Figure 2 shows a PAN transmitter-personal monitor communicating with a PAN receiver – vibration device. Both devices are battery powered, electrically isolated, and have a pair of electrodes.

The PAN transmitter capacitively couples a modulating picoamp displacement current through the human body to the receiver. The return path is provided by the "earth ground," which includes all conductors and dielectrics in the environment that are in close proximity to the PAN devices. The earth ground needs to be electrically isolated from the body to prevent shorting of the communication circuit.

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, relative to the earth ground, 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. The earth ground provides the return signal. [1], [2], [3]

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 3 x 1.2 cm and its earth.

A similar pair of flats was used as the receiving part, as shown on Fig.3.

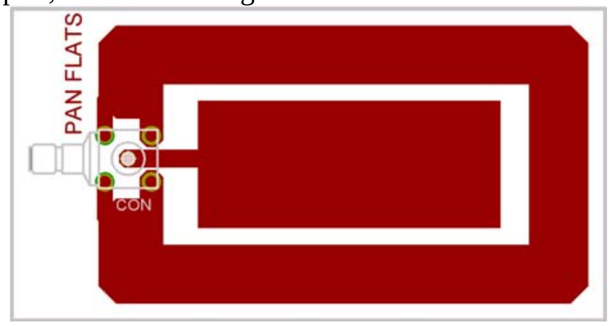

Fig.3. Layout of transmitting and receiving flats

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 on Fig. 4

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.

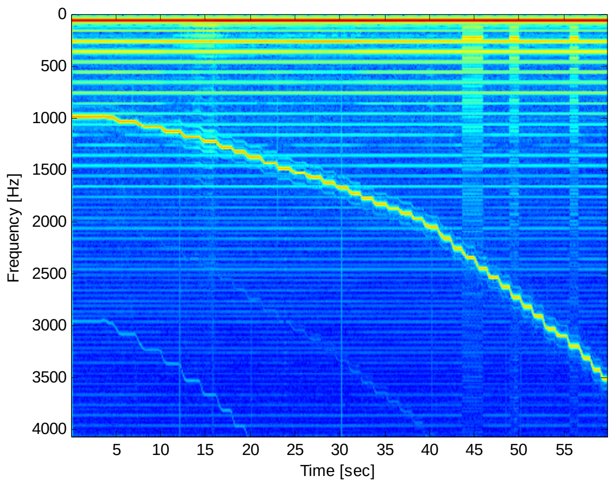

Fig.4 Record spectrogram

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.

3 Development of a PAN prototype

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 flow chart is shown on Fig.5. The high-frequency signals from the individual sensors are captured in the VHF 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.

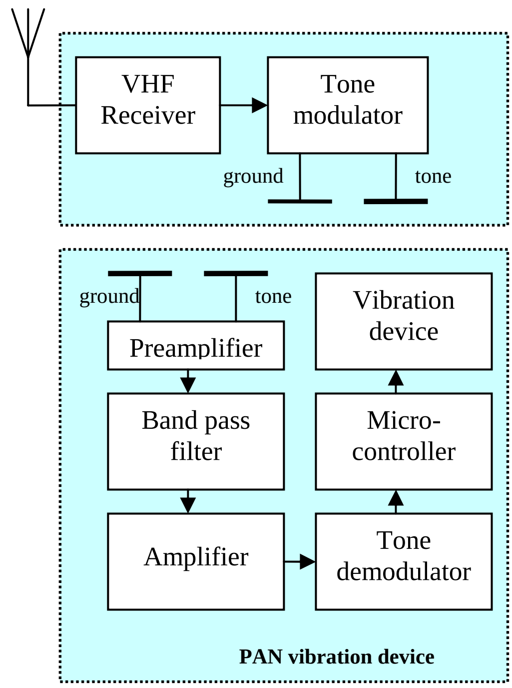

Fig.5 PAN prototype block diagram

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 sensors and violation types from sensors, such transfer speed is fully sufficient because of the used index addressing. PAN prototype photograph can be found on Fig. 6.

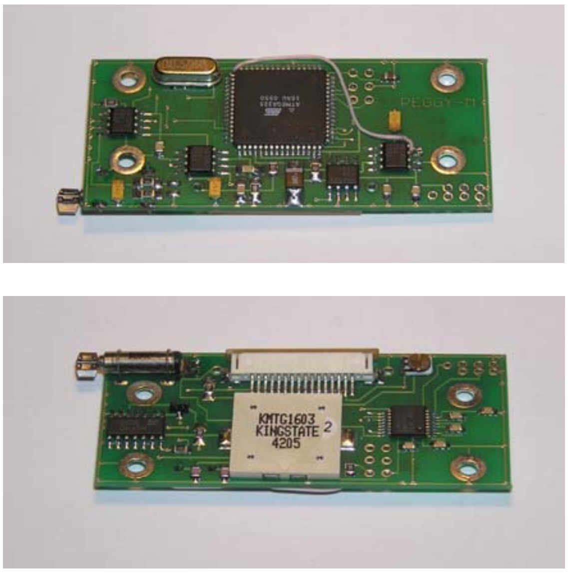

Fig.6 Picture of the PAN prototype

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.

3 Conclusion

A practical example of PAN usage for violation indication in connection with UGS 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, because the same modulation is used also for the high-frequency transfer. 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.

In its principle, the vibration device is in fact circumferentially identical to the UGS receiver, only the high-frequency VHF route is replaced with the low-frequency amplifier and with the band-pass type filter.
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. 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.
As the vibration device is located in the operator's shoe and is fed by its own flat Li-Pol accumulator, additional charging of the accumulator will have to be solved in the future. The methods and options of the self-powered device has already been published in several documents and can be found e.g. in [4],[5]. Especially due to the above-mentioned reason, the circuit option with the electric input of approximately 3μW without the vibrator engaged was chosen.

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