Abstract: - This paper is directed to the area of the Unattended Ground Sensor – UGS for perimeter guarding use. It has been developed the sample of the new UGS conception. The main characteristics and digital signal processing principles are presented in this article. The proposal method how to localized plenty of UGS are presented too. It is currently more and more evident that passive means of intruder detection within a perimeter using most up-to-date technologies are going to be introduced in the most up-to-date military and security systems.

Key-Words: - UGS, Tracking, Localization, Magnetic sensor, Seismic sensor, PIR sensor, Tamper sensor.

1 Introduction

In early 1990s development of new sensor systems began on the basis of experience with applications of the STEALTH technologies for selected types of military technology. The new sensors are able to detect, identify and localise targets equipped with this technology. Due to the ever increasing number of terrorist attacks of both civil and military targets emphasis was laid on development of new sensor systems not based on the radiolocation principle but employing progressive principles and technologies based on physical principles of activity other than radiolocation. This means physical manifestations of intruders’ activities – targets that are difficult to mask – such as acoustic, magnetic, seismic or optical manifestations. The significant and motivating reasons for development and testing of new sensor systems include the fact that these sensors usually do not need electromagnetic radiation for their activity. Their passive activity allows hidden placements of the systems in the guarded locations and makes it very complicated to discover them with common investigation technology.

1.1 Passive Sensor System as Viewed by User

To summarise the current development trends, not only in our country but also worldwide, in the area of sensor systems able to detect targets on a passive basis and on the basis of the abovementioned physical manifestations of the target, the systems, which are usually relatively similar in nature, can be characterised with the following utilisable properties:

- A sensor system consists of several independently working sensors equipped with physical quantity detectors – sensors. Reporting about intruder goes via a radio channel to a portable PC monitor to be displayed there; in some cases the monitor is connected to a PC for further processing of the reports.
- An external geophonic sensor is used for target detection on the basis of its seismic manifestations.
- An external magnetometric sensor is used for target detection on the basis of its magnetic manifestations, or the magnetometer can be included in the sensor and behave as an independent part of the system.
- A passive pyro-sensor is used for target detection on the basis of its infrared irradiations, usually within the reach of several dozen meters.
- The system often does not include any retranslation unit, or a retranslation unit is created by metallic interconnection of two otherwise functioning parts of the system.
- The software configuration of the individual system sensors is limited.
- Sensor functionality extension by further sensor parts is limited too.
It is also worth mentioning here that not all of the presented sensor systems are commercially available and system modifications on customer request are limited. [1], [2], [3], [4], [5]

2 Universal passive sensor

2.1 Description
Universal passive sensor forms the core of the whole system. Since the very beginning emphasis has been laid on its universality as well as usability value. The main benefits represented by the sensor include integration of a magnetic and a seismic-acoustic sensor into a single functional unit. Instead of a standard geophonic sensor use of piezoelectric materials proved to be effective replacement of all mobile mechanical parts, providing for reduced weight of the sensor and no need for connector. The application of a universal bus-bar and an integrated communication protocol allows extension of the sensor with other sensors that can either be integrated in the basic sensor or connected to the sensor as external device. The sensor functionality and all of the integrated sensors can be arbitrarily configured using the iButton technology, not only in the preparatory stage of the sensor introduction but also in the field at the installation point. The software of the algorithms of sensor signal processing and sensor activity control are provided by a microcontroller with extremely low power demand, which significantly extends the life of the sensor per charge of the inbuilt accumulators. The applied pyro-sensor allows intruder detection at a distance exceeding 100 metres with movement direction distinction.

2.2 Universal Sensor System For Perimeter Guarding
The universal sensor system consists of an optional number of separate independently working sensors communicating via a radio channel with a PC monitor and a retranslation unit. All of the sensor forwarded reports are registered in the PC monitor and notify the user about received reports by optical, acoustic or vibration signal. The retranslation unit forwards the reports into the receiver. The receiver further forwards the reports, in digital format, to the connected PC, a pocket computer of the iPAQ technology. This computer clearly displays information from the individual sensors against mapping software background, registers the received reports and verifies functionality of all sensors, including the retranslation unit and the receiver.

Fig.1: Individual parts of universal sensor system

The computer further contains software for programming of the individual parts of the system with the help of iButton technology and elimination of user mistakes in configuration of all parts of the universal sensor system. For the individual parts of the system see figure 1.
The universal sensor system consists from these main parts, which are integrated into the aluminium waterproof case:
- The geophone and the pre-amplifier parts. It is possible to use the piezocable instead the in build geophone. The digital signal processing with the adaptive detection threshold is able to classify intruder between a person or a vehicle. The detection range is more than 45 meters for personnel.
- The two-axis magnetometer with digital data output. This magnetometer can detect metallic objects in the range up to 15 meters.
- The TAMPER sensor, which detect any unaccepted movement or vibrations of the aluminium case.
- UHF transmitter – receiver that allows half duplex RF-VHF communication with the others sensors. It is possible to use the universal sensor as the receiver as the retranslation unit too.
- Li-Pol battery with internal charger and protection circuits allows properly work of the universal sensor system for couple of weeks.
- The real-time circuits can switch on and off the universal sensor system in the pre-programmed frames.
- The integrated optic-coupler switch, it is possible to connect any external sensor, which is equipped with switch on or switch off contact. As the simplest sensor can be used, for example, wire-loop.
- The serial input for programming in build micro controller and internal real time circuits.
- The serial output for sending received data to the iPAQ or the personal monitor or any PC.
- External PIR sensor, which can detect personnel up to 120meter range. There are tree main types with different detection range: 15, 40 and 120 meters. These PIR sensors can resolve direction of the movement from the left to the right and vice versa.

The block diagram of the universal sensor system is in the figure 2.

2.3 Digital signal processing
Even if there are lots of numerical methods for the digital signal processing running in the real time, it is useful to say, that all computation process must be realized via supply of two Li-Pol battery for the duration a few of weeks. Therefore it is not possible to use standard DSP processors because any microampere of the current consumption is critical. The best solution is to use microprocessor with the prefix Nano-watt technology, for example PIC18F2220. All digital processing is based on non-linear filtration, Bayesian detection and cluster analysis.

2.4 Application of Passive Sensors
Potential application areas for passive sensors are so versatile that their exhaustive list cannot be provided. The principal advantages of the universal sensor systems, as mentioned above, include its use of passive sensors. The universal sensor system placement is in the figure 3. Further advantages include the fact that the sensor installation in the guarded area takes a very short time and yet the sensor is well hidden in the landscape, thanks to its underground location. That is why discovery of this sensor is very difficult, which make the user benefit from concealed guarding. The high-frequency broadcasting is only transmitted on the sensor activation (and in optional periodic intervals for self-control of the sensor activity) and takes a couple of milliseconds, which makes it difficult for the enemy to detect the sensor with its investigation means and to interfere with it with its electronic fight means. Passive sensors provide for continuous economic control of large areas. Passive sensors reduce the number of persons otherwise needed for surveying and investigations of large areas and significantly reduce potential risks these persons would otherwise be exposed to. The passive sensor system consists of individual sensors with integrated sensors, retranslation stations and evaluation stations.
The sensors, the retranslation and the evaluation stations form an integrated network providing general survey of and timely warnings within the guarded area. The passive sensor system can be used in most of the tactical operation types. Optimum areas for use of the system include areas where the intruders’ movement is limited to a couple of key points or access routes, communication nodes etc. The passive sensor system is ideal for use in relatively stabilised situations such as short- or long-term defensive or security missions providing sufficient time and resources for development of a large sensor network.

Priority requirement for passive protection usually comes from localities with thick forests, articulate surface or unknown territories in combination with unfavourable climatic conditions ruling out or at least limiting effective guarding. The system represents a precondition for the operating group or unit full concentration on quality and success of the task for which it was trained and summoned. For this purpose the passive sensor system is ideal, as the sensors are quick to install in the selected locality and able to provide timely information about approaching threat.

4. Target localization
Problems of sensors for detection of presence and movement of subjects, vehicles and other objects cover many different research areas. First of all, it concerns domains for selection of sensor operation principle, information transfer method, power supply, method of sensor transportation into a service area, etc. Problems of sensor localization in the given area and with requested precision is another, no less substantial domain. This requirement is critical in such a case especially, when particular sensors are dropped from an airplane. Although UGS miniaturization is going ahead by leaps and bounds, still even in the future it would not be easy to integrate GPS antenna into acceptable size of currently developed UGS. Moreover, for the strategy of UGS located in the service area in high numbers, GPS receiver integration to any unit does not seem to be profitable economically.

Generally, due to a relative short detection range of the UGS, it is the task to find position of an active device (signal source), which is detecting a target, by a passive system. Such a task can be solved by the basic method of signal source finding, which is triangulation, or by means of complicated methods of signal source finding. The TDOA (Time Difference Of Arrival) method fits into this group of methods. If we apply the triangulation method, it is necessary to appoint a method for direction finding. Method of amplitude or phase measurement appears to be available.

The triangulation method is based on source direction finding from at least two reception stations on two different positions and on the consecutive calculation of source position by the triangulation method. Application of the triangulation method using amplitude method of source direction appears to be disadvantageous. Likewise, application of TDOA methods for localization interferes with array of technological and tactical issues.

Most convenient system for UGS localization is based on phase interferometer. The phase interferometer finds direction to the signal source pursuant to received signal phase difference measurement by two different antennae and pursuant knowledge of frequency
of the signal. Requirements for the phase interferometer can be summarized to following points:

- Antenna base length of 1 meter is sufficient for unambiguous direction measurement with reference to UGS signal wavelength.
- Precarious knowledge of the received signal frequency band does not rise requirement for its measurement, so it would not contribute to the summary error of direction measurement.
- Antennae radiation patterns can be wide in order of tens of grades.

Solution of sensor localization is optimally executable with a passive direction finder using the triangulation method of signal source finding with measurement of direction to UGS by means of the phase comparative method.

Result of the simulation is presented in the figure 4. It has been used number of 40 UGS placed in an area of the 22km².

The post processing result gives to us the right UGS position and we can easily to estimate target’s moving direction and speed. The iPAQ is a suitable lightweight device for this task. The example of the mapping software is in the fig. 5.

5. Conclusions

It is currently more and more evident that passive means of intruder detection within a perimeter using most up-to-date technologies are going to be introduced in the most up-to-date military and security systems. The VZ-0000402 project supported by the Faculty of Military Technology has verified that the currently available sensor technologies and other necessary parts and accessories allow the recent efforts in this area to bear fruit in the form of particular devices produced and used in the Czech Republic.

References: