DETECTION OF IMPROVISED EXPLOSIVES DEVICES ON PERSONS AND IN BAGGAGE

Jaroslav Turecek
Police Academy of the Czech Republic

Summary:

In this article an overview of physical principles of detection of Improvised Explosives Devices during routine checking of persons and baggage are described. They include metal detectors, x-ray systems based on dual energy, back scatter, CT or diffraction, quadrupole resonance, detection of trace particles with equipment as GC, ECD, IMS or MS, neutron methods, millimeter or terahertz waves etc. Some limitations are pointed out. It is focused on both principled faults of detecting equipment and faults in utilizing. It is necessary to introduce in practice lately developed portals for checking persons and devices for checking baggage which are based on new physical principles. Security screening is unreliable in case only one physical principle of detection is used. If more physical principles are used the smuggling of a masked IED is practically impossible.

Key words:

Improvised Explosive Device; detection; x-ray; trace particles; millimeter waves.

1. INTRODUCTION

Reliable detection of Improvised Explosives Devices (IED) on persons and in their baggage is demanding from the technical point of view but such detection is at present generally considered possible and at the same time necessary in case of entrances into important and sensitive objects, e.g. aircraft, important government buildings, nuclear power plants etc. To secure a more reliable protection against bomb attacks it is necessary to know physical principles of detection technology and its weak points. Suitable set of detection devices should be used.

2. CONTEMPORARY SCREENING DEVICES

The typical contemporary body and carry-on baggage security screening systems usually consist of a walk-through arch way metal detector, a hand-held metal detector, an x-ray system for baggage screening, usually with dual energy (from one angle of view), rarely with a back scatter or an effective computer tomography, sometimes of an explosives detector mostly with the manual sampling by vacuuming vapours and wiping surfaces. Recently the walk-through portals for the detection of explosives traces have come into use. Exceptionally traditional x-ray systems are used for people screening.

Metal detectors detect electrically conductive materials on the principle of induction of vortex currents and ferromagnetic metals on the principle of changes of orientation of magnetic domains. They do not detect non-magnetic or electrically non-conductive objects. It means they do not detect cold arms made of plastics and composites, drugs, ceramic shooting guns. They do not detect explosives at all. Despite this fact they pose a certain complication for the IED to be smuggled through.

Walk-through metal detectors usually detect electronic part of the ignition system with a battery (it depends on its size and the pre-set sensitivity of the detector). But the electronic part can be built in a harmless common consumer electronic device screened during the x-ray carry-on luggage screening. One of the significant elements enabling the detection of IED is the detonator. The detonator can be more probably installed in the direct contact with the explosive. Its metal shell made from copper or aluminum, in some cases, activates the alarm in metal detectors. However, the walk-through metal detectors are routinely adjusted not to activate the alarm when people carrying small metal objects (e.g. watches or metal buckles) and so they will hardly detect metal cases of detonators.

Using the hand-held metal detector metal objects can be localized quite easily but it is difficult to assess their size. The signal power is in this case much more dependent on the variable distance of the detector and the metal object than on the size of the object. And more over the screened people usually have a lot of metal objects on their bodies. After removing the object that activated the alarm the screened person should walk again through the walk-through metal detector because only a negative detection by this detector guarantees that the screened person has no bigger metal object (conductive), for instance a battery.

Recently boots metal detectors capable of comparing the signal symmetry emitted from the boots have come into use. They are useful for the detection of smaller weapons hidden in the boots.

The metal detectors themselves are thus only a bit unpleasant obstacle for the carriers to smuggle explosives through. But on the other hand the walk-through metal detectors make it inconvenient to pass through the IED igniter. One fact is very important, the detectors thwart electromagnetic shielding of the explosive, for instance by an aluminum foil, from the detection by another methods.

X-ray systems are the most widely spread devices for security checking of baggage. Besides simple absorption of x-ray radiation they also use the method of backscattering (Compton scattering), dual(multi) energy (of x-ray photons), computer tomography (CT) and x-ray diffraction.

Simple absorption of x-rays complies with approximate empiric relation $I = I_o\ e^{-\mu \cdot d}$. Here I_o [W m^{-2}] is the original intensity of falling radiation, I is the intensity of the radiation that has come through an object of the thickness of d[m] and μ [m^{-1}] is the overall linear absorption coefficient. These X-ray machines without automatic detection of materials corresponding to explosives are not sufficient for a reliable explosives detection. A big problem in the evaluation of x-ray images of the screened baggage is the monotonous job done under the stress especially in peak hours.

The essential thing is that the linear coefficient of attenuation μ depends on the density and effective proton number Z_{ef}. The linear coefficient of attenuation rises depending on the increasing Z_{ef} and Z_{ef} follows approximately average proton number Z. X-ray machines with *dual (multi) energy* scan two (more) x-ray images of the controlled object from the same angle but for different wavelength of x-ray radiation. They use the fact that the coefficient of absorption also depends on the wavelength of x-ray radiation. These x-ray machines are able to determine the effective proton number of the material of the controlled object from computer comparison of the two (multi) x-ray snaps. Explosives are then automatically detected just on the basis of their density (effective proton number). However, there are a lot innocent materials that have the very similar density as some kind of explosive. It results in a lot of falls alarms (about 20 %).

The overall linear absorption coefficient is given by the total sum $\mu = \mu_f + \mu_c + \mu_p$, where μ_f is the coefficient of attenuation given by photoelectric absorption, μ_c is Compton scattering and μ_p electron pair production. The attenuation coefficient μ_c given by backscattering falls down if the proton number rises, which means that backscattered x-ray radiation is the most intensive on substances with a low proton number, it means especially on substances containing a lot of hydrogen. *Back-scatter* x-ray detectors help the staff because back scatter is more intensive in explosives than in inorganic materials. But it is hardly to distinguish an explosive from a harmless organic material.

Security x-ray machines with *computed tomography CT* scan x-ray images of the object from more different directions (also rotating around) and these images are then mutually computed. On the basis of this comparison we are able to determine absorption of x-ray radiation in individual imaginary flat layers of the examined object (tomos = layer). We can guess the material density, in this case it is marked as CT density (in kg . m^{-3}). Interest substances, explosives or drugs, are then detected just on the basis of their CT density.

The automatic detection of a suspicious material mentioned above draws the attention of a security operator on a marked area on the screen. The basic activity of x-ray systems operators is the searching for a signs of IEDs, for example a detonator in the object that could be an explosive.

Typical contemporary **trace particles detectors** take samples by vacuuming of vapours from the vicinity of the controlled object or by wiping its surface. The analysis part itself consists in a lot of different principles as chemical methods and their mutual combinations, e.g. electron capture detection (ECD), (dual) gas chromatography (GC), preselection by a semipermeable membrane, various preconcentrations on special surfaces, Ion Mobility Spectroscopy, modern up-to-date biosensors or various methods of effective but rather expensive mass spectrometry. Vapour detectors are not able to find the explosives with insufficient tension of their vapours or tightly sealed IEDs.

X-ray systems for people screening are based on backscatter principle. At present it is rather a lengthy procedure to scan people by contemporary backscatter x-ray systems, because a person has to be scanned from at least two sides, at best from four sides. The scanners developed on new physical principles of the scanning system usually work on the basis of rotation around the standing person. The main problems of using x-ray systems are legal objections against the irradiation but these objections are not justifiable regarding to very low doses of about 0,05 μS. The public quite irrationally oppose not only the irradiation itself but also the exposing of intimate parts of a body. It is reasonable but at the same time disputable.

3. ADVANCED EXPLOSIVE DETECTION SYSTEMS

At present two groups of advanced x-ray systems for screening checked baggage are introduced. It would be necessary to reduce the size of these systems for hand baggage screening. The first of this group is using the method of *dual energy from several angles of view* during one passage of this piece of luggage. These x-ray systems detect explosives in contrast with computer tomography during the uninterrupted movement of the conveyor. These x-ray methods also detect an explosive on the basis of density and an effective proton number of the material as well as dual energy and CT do it.

X-ray diffraction poses an exception. In x-ray diffraction a beam of x-rays, of wavelength lambda, are incident on a specimen. The beam will be diffracted by the crystalline phase at an angle θ according to Bragg´s Law: $\lambda = 2\ d \sin \theta$. An explosive is precisely detected according to the distance of its atomic levels.

Nuclear quadrupole resonance (QR) is suitable advanced method of the volume detection in the hand-held baggage that exactly detects the explosive. Quadrupole resonance uses specially tuned, low frequency radio wave pulses that momentarily disturb the nuclei of nitrogen in explosives. At the end of the pulsing, the nuclei realign and send out a weak radio signal of their own. The signal emitted depends on the molecular structure of the atoms, so each target material is unique. The sensor coil picks up this weak signal and a computer rapidly analyzes it to determine the presence and type of material found. Unlike Magnetic Resonance QR does not use strong magnetic fields. Inspection time can be quite long if we want to detect more types of explosives and metal items can shield the explosive.

An equipment based on **neutron radiation** will probably be a necessary part of the combination of systems for advanced security screening of baggage because even thicker metal sheets do not shield the explosive.

The simplest of them, *neutron backscattering*, consists in the irradiating of the controlled object by a beam of fast neutrons followed by thermalized neutrons detection – i.e. the neutrons slowed down on the nuclei of hydrogen atoms. Considering the backscattering of neutrons an innocent material will show characteristics of the original explosive supposed it has a higher number of hydrogen atoms. This method can have a lot of falls alarms in the case of unsuitable application, but it can also be an cheap irreplaceable supplement of x-ray systems for screening of notebooks, various kinds of electronics, bigger bulk of metal tools and so on.

More progressive methods are neutron activation of gamma radiation, "*neutron-in, gamma-out*" methods. These methods are based on the irradiation of the controlled object (luggage) by a beam of neutrons and the measuring of the subsequent gamma radiation induced by the neutrons in the material of the controlled object. The simplest of these methods is Thermal Neutron Analysis (TNA) that irradiates the object by slow (thermalized) neutrons with the subsequent detection of gamma radiation as a product of the capture of a neutron by a hydrogen or nitrogen nucleus contained in the explosive. Other methods, for instance Fast Neutron Analysis (FNA) and Pulsed Fast Neutron Analysis (PFNA) detect carbon, oxygen and nitrogen. Pulsed Fast-Thermal Neutron Analysis (PFTNA) detect carbon, oxygen, nitrogen and hydrogen. Nanosecond Neutron Analysis /Associated Particles Imaging (NNA/API) can detect even other elements. However, neutron-in, gamma-out" methods are often time consuming and they cannot be used for screening people.

The detection of explosives hidden under the clothing of people is the main problem. The urgent need to solve this problem sped up the development of several new principles.

For a long time there has been offered a principle of a passive imaging of electromagnetic waves – thermal radiation of objects, especially a human body, in wavelengths of the range of infrared radiation and radio waves – of about 3 mm. This imaging is also known as „**millivision**“. On the contrary to the classical thermal imaging in the range of 2-5 μm and 8-15 μm, waves of millimetres length penetrate well through the clothing and in contrast with longer electromagnetic waves the image resolution is possible to be used to distinguish a bigger bulk of an explosive hidden under the clothing from a human body. These devices are unique because they can be hardly substituted and they are able to image in real time the contraband hidden under the clothing of people in the range within a couple of tens of metres. Protests by the public against health threats are not taken into consideration. Protest can be acceptable only from the point of view of the protection of privacy, but it is also disputable. To mask a bigger package containing an explosive against this passive system detection appears very difficult. However the servicing staff will hardly be able to distinguish between an explosive and a harmless organic object. In this range of wavelength it is not possible to determine different kinds of materials.

A relatively perfect three-dimensional image of a body of a scanned person and all objects hidden under his/her clothing can be made by arch way scanners based on **active holography imaging** using electromagnetic waves of the length of approximately 1 cm. The servicing staff could easily detect a contraband on 3 D image showing an improper shape of a human body caused by this contraband. As well as in the case of back scatter x-ray detectors and passive imaging of millimetre waves the software to suppress private details of a body is being developed from the reason of privacy protection.

So called **dielectric portal** will function on the principle of the automatic detection of the contraband carried under the clothing of the scanned person. It will be a big advantage preventing from a human-made mistake. This scanner measures dielectric constant of a human body surface by means of the determination of the reflection coefficient of microwave radiation. The unique character of this device consists in the fact that the shape of the object is not important. The decisive criteria for the automatic detection of the object on the skeleton generated on the screen by the computer are the size of the object, the density of the material and its absorption abilities. The disability to recognize and display a shape means that this technology does not cause inconvenience to the scanned persons. The archway identifies as suspicious all bigger objects that the scanned person has on him/her. It does not detect explosives and no image of suspicious object is seen by the staff. It means bigger number of “falls” alarms.

In contrast with the above mentioned screening systems detecting only a bigger object under the clothing **nuclear quadrupole resonance** (NQR) would detect the explosive itself. This is a prospective method how to improve persons screening because unlike the baggage screening it would not have to deal with the issue of the penetration through metal materials. At present owing to the metal detectors all bigger metal objects are, during the security screening, referred to the baggage screening. The advantage is the automatic explosive detection regardless of its placing, tension of vapour at the given temperature, vacuum sealing etc.

Very promising method is the use of **terahertz waves** – terahertz imaging and/or spectral analysis of terahertz waves reflected from the scanned person. Apart from producing images with very high resolution this method would also enable to identify the kind of material hidden under the clothing,

4. CONCLUSION

Security screening is unreliable in case only one physical principle of detection is used. If more physical principles are used the smuggling of a masked IED is practically impossible. Less percentage of failures and falls alarms is not a sufficient reason not to introduce these devices. The terrorists will find it extremely difficult to overcome the barrier created by the combination of more highly automated and mutually cooperating physical principles.

REFERENCES

Schubert, H. Rimski-Korzakov, A. (eds) *Stand-off Detection of Suicide Bombers and Mobile Subjects. – NATO Security through Science Series*, Springer, Netherlands, 2006, p. 151-165, ISBN 1-4020-5158-1
IDO Security 2000, 6 Sapir Street, New Industrial Area, Rishon Lezion, Israel, www.idos2000.co.il
PerkinElmer Detection Systems – Automated Systems, 10E Commerce Way, Woburn, Massachussetts 01801, http://instruments.perkinelmer.com
Millimetrix, 100 Venture Way, Hadley, MA 01035, www.milivision.com
Safe View, Inc., 469 El Camino, Real Suite 110, Santa Clara, CA 95050, www.safe-view.com
Spatial Dynamics, Inc., 1847 Wilma Drive, Clarkston, WA 99403, USA, www.spatialdynamicsinc.com
TeraView Ltd., Platinum Building, St John's Innovation Park, Cowley Road, Cambridge, CB4 0WS, www.teraview.com