SECURITY SCREENING OF EXPLOSIVES IN BODY CAVITIES

Assoc. Prof. Dr. Turecek J. PhD.[1]
Police Academy of the Czech Republic in Prague, the Czech Republic [1]
jaroslav.turecek@mymail.cz

Abstract: *Suicide bomber attackers with improvised explosive devices hidden inside their body cavities may be a new danger to air transport security. Metal detectors, passive and active millimeter or terahertz waves imaging, x-ray backscatter imaging and portals for trace particles detection are not sufficient for detection of explosives concealed under thicker layer of material with density and dielectric properties like human body. Through x-ray imaging is problematic for public health regulations and so only nuclear quadrupole resonance seems to be the solution.*

Keywords: EXPLOSIVES DETECTION; BODY SCANNER; QUADRUPOLE RESONANCE; BODY CAVITIES

1. Introduction

It wasn't so long ago when a possibility of suicide bomber attacker with improvised explosive device hidden inside his body cavity seemed to be an absolutely absurd idea for an airport security staff. Nowadays, this danger becomes a reality. Detecting explosives in body cavities of a larger number of passengers is from a health and ethical point of view very difficult, but not impossible. This possibility should be taken into account when developing a new detection technique.

2. History of development of technologies for person security screening

At the end of the last century, airport security screening of passengers was based only on walk-through metal detectors complemented by handheld metal detectors. These devices detect only metal firearms, cold weapons and munitions such as hand grenades, etc. For the era of airplane hijacking with pistols and even automatic submachine guns, screening of passengers with metal detectors and baggage screening with x-ray systems simple imaging of passing through x-rays was sufficient. An important milestone was the bomb attack on December 21, 1988, on the Pan Am 103, when the Boeing 747, after the explosion of about 300 to 400 grams of plastic explosive, probably Semtex 1H, fell on the Scottish town Lockerbie. This incident pointed out the need to develop appropriate techniques for the detection of explosives, mainly plastic explosives inside checked-in baggage of passengers. However, suitable technologies were not at sufficient level. The introduction of relatively sufficient countermeasures took many years. In the field of trace particle detection, this led to the Montreal agreement on the compulsory marking of plastic explosives for the purpose of their detection, signed in Montreal on 1 March 1991. This Montreal Agreement entered into force on 21 June 1998. However, a lot of trace particles detectors were not able to detect these markers even after its entry into force. Even the achievement of sensitivity applicable for detection of pentrite and hexogen, explosive components of plastic explosives, had taken a long time. In addition, the negative trace explosives detection during a baggage security screening is not generally sufficient to approve that there is no explosive in the luggage. In the field of volume detection of explosives, the development of technology has led to the introduction of dual-energy x-rays systems and, partly, x-rays systems with CT.

A terrorist attack on September 9, 2001 on targets in New York and Washington, using 4 hijacked aircrafts, highlighted the need to secure the doors to pilot cockpits and search more thoroughly for cool weapons on passengers. However, metal detectors were the only widespread technology for detection of cool weapons on human body at that time. Body scanners have begun to be improved significantly more, but their implementation into security practice was very slow and on a very small scale. Even though there were another warnings.

The first one was the revelation of the London plot on August 10, 2006, when terrorists had planned to take liquid explosives precursors aboard several aircrafts. This highlighted not only the need of equipment for searching for liquid and gel explosives and their precursors in handheld luggage, but also the need for body scanners to check whether the passenger had taken out all the containers and submitted them for inspection and whether the passenger had nothing hidden under his/her clothing. Detection equipment for reliable and quick analysis of liquids and gels in containers inside hand held baggage has not yet been developed so all containers with liquids must be taken out from hand held baggage and put separately into an analyzer of liquids.

Another impetus for body scanners was a failed bomb attack on NW 253 flight on Christmas Eve 2009, when young Nigerian man was smuggling 80 grams of plastic explosive of pentrite type in his slips. This terrorist attack failed only due to failure of complicated and clumsy initiation chain between TATP and other chemicals. However, body scanners may already have difficulties with this way of smuggling.

Contemporary body scanners are not able to distinguish between types of organic materials. Shoe soles can represent a relatively large volume of organic matter. This also inspired Al-Qa'ida when shoe bomber Richard Reid smuggled a plastic explosive of PETN type in the sole of his shoe on board of American Airlines 63 flight from Paris to Miami on December 22, 2001. This led to security countermeasures consisting of taking shoes off and putting them on x-ray conveyor belts, which is a rather inconvenient and delaying clearance of passengers. In addition, this security screening of shoe soles with dual-energy or CT x-ray systems relies on the attention of x-ray operators, and at the same time, on the limited technological capabilities and possibilities of the attackers, which have not yet been able to develop the soles of shoes and IED components from materials with a similar effective atomic number to each other. Such a system would be stealth to the operator of x-ray system. Drugs are also often smuggled in shoes. In technologically developed Japan, this fact has led to the development of advanced detectors of drugs in shoes working on the principle of nuclear quadrupole resonance for the needs of Japan customs at airports. Devices based on the same principle are also offered to airports for detection of explosives in shoes.

3. Possible technologies for detection of contrabands in body cavities

Currently deployed full-body scanners working on the principle of backscatter x-ray imaging or on the principle of active (or passive) millimeter wave imaging are not and will not be able to detect foreign objects in the human body cavities, let alone distinguish the type of its material.

At the same time, the so-called swallowers of smuggled contraband, especially drug packs, have been a long-established issue for customs officers around the world, especially at airports. A terrorist attack with NVS hidden in body cavities was already carried out, though not on an airplane. It was Al-Qaeda again, Abdullah Hassan al-Asiri, on August 28, 2009, attempted to commit suicidal assassination on Saudi Arabia's interior minister, member of the royal family, Muhammad bin Nayef. It was estimated that 100g of pentrit type plastic explosive was used. The IED was hidden inside his anal cavity together with a detonating system, probably based on a mobile. The explosion was likely triggered by repeating the phrase by the attacker. The body of the suicide attacker fortunately significantly diminished the effects of the explosion and Muhammad bin Nayef was only slightly injured. This raises the question of how big of a threat to an aircraft is the explosion of IED in the body cavities of a suicide attackers. Above all, the question of the possibility of detecting explosives in the body cavities arises here. Imaging of the items smuggled in the body cavities and distinguishing types of materials is physically possible with x-ray computer tomography or x-ray diffraction systems. This is, however, impossible in security practice. It is not just about the high purchase prices of these devices and their lower speed of passenger clearance, besides these parameters may be improved in the future. A serious problem is the association with higher radiation doses per a scanned person, which are only justifiable for medical purposes. On the other hand, since no contraband should be hidden in body cavities, it is not necessary to use high doses of x-ray radiation to recognize specific types of materials.

The suppliers of x-ray systems specializing in the search for contraband in body cavities of people have existed for many years. These scanning systems are based on simple x-ray imaging. The simple image of passing through x-rays reveals all the larger foreign objects in the body cavities and at the same time under clothing. What's more, the x-ray operator is usually able to distinguish drug packages from an IED. They work on simple x-ray imaging with minimal radiation dose per person and scan. These doses are minimal but larger than doses in x-ray systems, which visualize only x-ray radiation backscattered from the surface layers of the human body. Extremely low irradiation is sufficient for x-ray backscatter systems. Despite this fact, even backscatter x-ray body scanners tend to have problems, albeit hardly justified, with their approval to operate at airport security checks in most countries.

In the near future reflected terahertz radiation spectroscopy seems to be convenient method to determine types of materials under the clothing of passengers. In the further future, the active terahertz three-dimensional imaging with the spectroscopy of the radiation reflected from each space point of the clothing of scanned person should be possible. Since human tissue contains many molecules of water, which strongly absorbs terahertz radiation, penetration of terahertz radiation through human tissue is very small.

“Neutrons in – gamma out” methods are totally inapplicable for scanning of persons for health reasons.

An excellent medical method of body organ imaging is nuclear magnetic resonance imaging. It uses a very strong magnetic field, which almost certainly destroys pacemakers and electronic devices in general. Serious problems can also be with knee joint prosthesis and similar prosthesis. Even in the hospitals, fatal accidents have been reported when nuclear magnetic resonance was accidentally applied to a patient with a pacemaker. The use of this method for passenger screening is therefore excluded.

4. Quadrupole resonance

It seems, that only the nuclear quadrupole resonance (QR - Quadrupole Resonance) method remains suitable for the detection of explosives and drugs hidden in body cavities of passengers. Quadrupole resonance is sister method of nuclear magnetic resonance but without a strong stationary magnetic field. It should be noted that this is not a nuclear reaction - a reaction during which changes in the composition of nucleus would occur. Only the electrical properties of the nucleus in the external electromagnetic field inside the radio wave range are measured.

Using this method, we can detect a presence of some atomic nuclei found in chemical bonds in the investigated space by electromagnetic fields inside radio wave range. This detection does not depend on spatial distribution of nuclei inside the investigated space. For police and security purposes, nitrogen nuclei found in chemical bonds such as pentrite, hexogen, TNT or chlorine are searched for.

The method is based on the fact, that nuclei with spin ≥ 1 generally have a non-zero electric quadrupole moment. The image of the electric quadrupole is well suited for describing the electric field of these elongated or flattened nuclei. During quadrupole resonance, a reorientation of the nucleus between its quantized orientations, relative to the electrical voltage, is observed. Simply, the moment of power acts on the non-spherical nuclear charge and causes precession.

During a nuclear quadrupole resonance measurement, transmitter sends a complex pulse of low-intensity radio waves into the luggage space. This electromagnetic impulse turns rotation axes of atomic nuclei of the investigated substances into the same angle. After the exciting impulse stops, the rotation axes turn back to the original angle, to the disarranged but balance state - state of equilibrium. During this turning back, the nuclei emits electromagnetic waves with special frequency, called resonance frequency, that is typical for the type of nuclei. This resonance frequency also slightly depends on the molecular band of these atoms. This resonance signal is captured by the receiver and immediately analyzed by the computer. The device usually searches for a stretched nucleus of nitrogen N14, located in explosives. Due to the environment of neighboring atoms, the resonance frequency is slightly shifted. As stated above, the size of this shift depends on the type of environment, from it we can deduce the type of molecule and hence the type of substance - whether it is PETN, RDX or TNT etc. QR is highly specific because the sensitivity depends on the shape of the molecules, it can detect the fabric anywhere in the controlled area, regardless of orientation and layout. QR can detects explosives formed into thin sheets and even explosives divided into separate packages or dispersed explosives, which can be abused by suicide bomb attackers. For the QR signal´s size, the total number of interest molecules in the controlled area is decisive.

QR devices were originally offered in designs convenient for luggage and consignment screening. The operator did not have to analyze any video or image output, he was directly aware of whether the inspected subject contained explosives or not. An analysis lasting a few seconds does not damage magnetic media, such as computer disks, and so on. QR detectors have very low rate of false negative and false positive detection.

Both the exciting signal and it´s response can be, of course, shielded with metallic, conductive objects. Therefore, there is an attempt to develop newer QR-based devices with metal detection capabilities to warn the operator of the possibility of shielding. In case of conveyor belt detectors of explosives in baggage, the screening of baggage with a larger metal content must be based on x-rays or other systems. This problem would not occur in the case of searching for explosives hidden under passenger´s clothing because all the larger metal objects are always detected by metal detectors and the passengers have to put them on x-ray conveyor belt. Still, the need for body scanners based on active or passive imaging of millimeter or terahertz waves or backscattered x-ray radiation imaging will exist. There can be another contraband than explosives under clothing of the passengers. It will be necessary to look for ceramic and/or plastic cold and fire weapons (fire weapons can be home made in 3D printers), as well as non-metallic containers with liquids and gels. Unlike nuclear magnetic resonance, the detection of liquid explosives by quadrupole resonance is practically impossible. Here, as mentioned above, scanning by terahertz spectroscopy will help. It is also necessary to note, that detection of vapors of liquid explosives is more effective due to higher partial pressure of their vapors. For reliable sealing of explosives without the use of metals (due to the detection of metals), glass would be appropriate from the point of terrorist´s view. On the other hand, glass is excellently permeable for terahertz waves.

The currently offered and developed QR portals are mostly intended for detection of explosives or another contraband hidden under passenger´s clothing, not for detection of explosives hidden in body cavities. An exception is the QR portal for detection of drugs, especially methamphetamine, which is being developed by professor Hideo Itozaki of Osaka University [1] for Japanese customs officers. The human body is a problem for the exciting and excited signal of quadrupole resonance. Fortunately, even in the case of swallowers, contraband packets are hidden very close to the surface of the human body, in this case the abdomen, namely 2-4 cm. This is small enough value for the successful detection of the contraband, if we take into account the range of values of electrical conductivity of different human tissues. Detection of methamphetamine in body cavities is on the limit of current technological possibilities. However, the signal from methamphetamine is extremely small. For example, it is 8 times weaker than from TNT explosive, that is considered difficult to detect by quadrupole resonance. The QR signal from RDX, the US military explosive C-4 and the British PE-4 component, is even 500 times more powerful. It follows that explosives in body cavities can be successfully detected by quadrupole resonance.

4. Conclusion

The only way to detect explosives in body cavities of passengers in routine security inspections at airports is quadrupole resonance. Devices may take the form of walk-through portals and handheld devices, much like metal detectors. Quadrupole resonance portals and handheld detectors can also simultaneously act as metal detectors. These devices will, of course, also detect explosives and metallic objects hidden under or in passenger´s clothing. Unlike metal detection, the quadrupole resonances detection of explosives will not be accompanied by permanent pulling of harmless nonmetallic items from personal pockets and their deposition on the x-ray conveyor belt. Body scanners will be needed to search for non-metallic cold weapons, firearms and containers with liquids. Although analysis of liquids found in containers in passenger´s clothing is likely to be possible by terahertz spectroscopy even without the need for extraction.

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