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Radiation-based techniques for use in the border protection context

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HIGHLIGHTS

- ▸ Radiation-based techniques used by border protection agencies are reviewed.
- ▸ Passenger portals use THz and mm-wave radiation, CCTV is used for crowds.
- ▸ For the examination of luggage, air-cargo, and shipping containers, X-rays are used.
- ▸ The need for excellent materials discrimination software is demonstrated.
- ▸ Materials discrimination using a combined neutron and X-ray system is described.

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ABSTRACT

Most airline travelers will be familiar with the current overt passenger examination procedures: metal detectors and small tunnel X-ray examination systems. The mix of overt and covert systems used to prevent dangerous goods and contraband from passing through the portal is constantly changing, dictated by policy decisions made by governments. The United States of America and the European Union are the largest regulatory bodies, and their procedures are adopted by smaller countries: Australia, for example.

This paper discusses a wide variety of techniques used by Border Protection Agencies. Most of these examination systems involve the use of the emission, absorption, and scattering of electromagnetic radiation and descriptions of these systems will comprise the bulk of this paper.

However, a brief discussion of the use of neutron scattering will be given to demonstrate how systems for the examination of large objects may develop in the future.

1. Introduction

When passengers enter the security portal of an airport they are requested to remove from their person many of their personal possessions: hats, coats, jackets, mobile phones, keys, wallets,…. The list seems endless. These are placed on plastic trays which are then examined with the passenger's hand luggage using a small tunnel X-ray system. But that is not the end of the pre-scan procedures. The passenger must remove any computers, bottles above a certain size, aerosol cans, and the like from the hand-luggage, and place them on trays to be X-rayed.

All this tests the patience of the passengers and adds significantly to the through-put time for the passengers, and hence the loading time for an aircraft. But it is necessary, because all governments are concerned about the possibility of bomb, hand guns, knives, and other dangerous goods being taken onto aircraft. They have regulations, for example, the European Parliament (2002), about what is not allowed: and what equipment and personnel will be deployed for the examination process.

But what the passenger sees does not necessarily reflect the totality of the examination to which he is subjected. A range of unseen systems may have scanned the passenger. He may have been examined by covert systems using passive or active THz radiation or mm-radiation. He will certainly been observed by Closed Circuit Television Systems (CCTV) and his image compared with lists of banned passengers.

Recent changes regulations may force the passenger to be scanned in an active mm-wave cabinet, or subjected to examination in a low energy low intensity X-ray body scanner. His carry-on baggage and other effects will have been examined by an X-ray system. As well, his hold baggage will have been examined by a more sophisticated X-ray system that that in the passenger hall.

In all, the passenger and his effects would have been examined by electromagnetic radiation spanning the photon energy range from <1 meV to 0.5 MeV.

I shall not discuss here the covert non-radiation-based examinations made by dogs trained to detect explosives and drugs, and systems using ion beam mass spectroscopy. Nor shall I address

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the complexities of facial recognition software for identifying suspicious people.

In discussing X-ray systems I shall concentrate on systems used in the passenger hall: small tunnel systems (<1000 mm $\times$ 1000 mm tunnel aperture). I shall not discuss the large pallet and shipping container X-ray systems used for examining air cargo and shipping containers. I shall, however, discuss the principles of operation of a new X-ray/neutron system for the examination of shipping containers.

2. Examination systems

A distinction has to be made, first, between ionizing and non-ionizing radiation. Ionizing radiation has sufficient energy to break chemical bonds and alter the genetic structure in cells. The boundary between the non-ionizing and the non-ionizing regimes could be thought to occur in the ultra-violet region of the optical spectrum ($\sim$350 nm), due to which skin cancers can be induced. For wavelengths longer than this the radiation is deemed to pose no health threat to humans. THz and mm-wave radiation fall into the non-ionizing category.

A distinction must also be made between passive and active systems. Passive systems are those in which the subject generates its own radiation. Active systems irradiate the subject with radiation.

2.1. Passive passenger portals

Passive passenger systems rely on measuring the black body radiation from the incoming passenger and the variations in spectral emissivity of the item carried from that of the passenger. The emission obeys the Stephan Boltzmann Law: energy flux density $=J=\varepsilon\sigma T^4$. Here ε=emissivity $(0<\varepsilon<1)$; $\sigma=$ $5.7604\times10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$; T=temperature (K). Currently available systems are sensitive to radiation from the person in the mm wave ($\sim$100 GHz) or the THz ($\sim$250 GHz) regions. The design and construction of mm-wave and THz detectors is a rapidly growing field (Knoll, 2000;Rieke, 2003; Lee, 2009). A wide range of multi-pixel semiconductor devices have been developed to operate at room temperature. These new detectors will be incorporated in systems using existing digital TV technology. Commercially available passenger portals tend to use only a line of detectors, and the image of the subject is scanned across this line onto the detector array using a tilting mirror (Fig. 1).

Several images are available to the operator: the Closed Circuit Television (CCTV) image; the raw image presented by the detector, and enhanced images (edge-enhancement, for example) (Fig. 2).

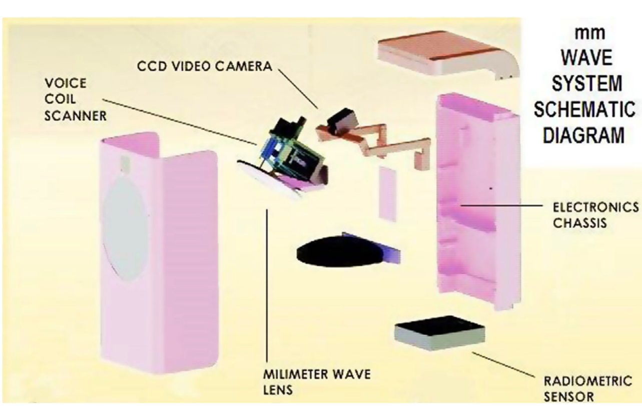

Fig. 1. Exploded schematic view of a mm-wave passenger scanner.

Fig. 2. CCTV and enhanced images of a passenger with a wallet in his hip pocket.

These systems examine only one side of the passenger. Either two systems have to be deployed so that the front and back of the passenger can be viewed simultaneously, or the passenger has to turn around so that a second image can be taken. Screening authorities, such as those in airports, are very concerned with "throughput", the number of passengers per hour passing the portal. As well, they are concerned with false alarm rates, both positive (there is a threat), and negative (there is no threat). Both have a deleterious effect on throughput.

Advantages of these systems are that: measurements can be made at a distance (stand-off capability); observations can be made whilst the subject is approaching the portal; objects at temperatures different from the body or having different emissivities will provide an image; the system can see what is hidden under a moderately thick layer of clothing; examination is rapid.

Disadvantages include: lack of materials discrimination; poor resolution; inability to detect items in cavities and crevices; inability to detect objects in the foot and ankle region; poor detection of objects not in contact with the body.

2.2. Active mm-wave passenger portal technology

Active passenger portals consist of mm-wave or THz generator and antenna system and a corresponding detector system. Beams of radiations are scanned over the subject, and an image corresponding to the point-to-point reflectivity of the subject is formed. In a sense this is a RADAR map of the subject. For portals which are large enough to encompass a human body it is necessary for the system to be enclosed in a cabinet because of radiation licensing regulations. In all countries the electromagnetic spectrum is divided into bands which are allocated to corporations and other entities by the relevant Broadcast Authority. Enclosing the system minimizes the problem of encroaching on another user's band.

By their nature these systems do not have a "stand-off" capability. Fig. 3 shows a photograph of a cabinet passenger mm-wave scanning system.

As well, an image of a passenger is shown. To meet the requirements of privacy legislation the outline of the image is a *computer generated anthropomorphic shape*. Some details of his clothing are evident. A circular shape has been placed around the genital area to ensure privacy. The operator can, however, turn off this privacy filter: but he has no visual contact with the subject. The passenger is rotated through 180° to ensure that both front and rear images are produced. Images of three square objects of