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# Survey of Methods and Techniques for Metal Detection

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**Abstract:** A physical protection system (PPS) integrates people, procedures, and equipment for the protection of assets or facilities against theft, sabotage, or other malevolent human attacks. The design of an effective PPS requires a methodical approach in which the designer weighs the objectives of the PPS against available resources, and then evaluates the proposed design to determine how well it meets the objectives. Many techniques have been used to detect the weapons and metal in different medium. The work propose the advantage and disadvantages of the methods.

**Keywords:** Metal, Weapon, Electromagnetic, Ultra Sound and Image Process

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## 1. Introduction

The incident at the U.S. Capitol showed the limitations of current security-detection portal systems—they must be near an individual to work. They generally provide sufficient warning when it comes to detecting a knife, but they cannot detect weapons that can kill beyond arm's reach. By the time a handgun or a bomb vest is detected, it generally is too close to be dealt with safely. But there are ways to provide more warning. One is to move the portal farther from the operator. For example, it can be incorporated into a building's entrance and operated from a control room at another location. A person who wants to enter the building is then required to first go through the portal before an interior door opens to allow admittance to the building. If the portal detects a weapon, the operator does not open the interior door or the door locks automatically, without the operator's intervention. To further protect the public, exterior doors open only after a second interior door is closed behind the person who has entered. In this way, only one person at a time can enter the building, preventing the possibility that innocent bystanders would be trapped in an entryway with an armed person. Despite their advantages, remote portal weapons-detection systems have significant limitations. They require more space for the remote location, which is not always available, and

they impede traffic flow. Using a remote exterior door with screening equipment and a second interior door in a crowded venue, such as a sporting event or an airport, would impede the flow of pedestrian traffic and cause people to collect in a relatively small area, creating a prime target for a suicide bombing or other attack. Another approach to detecting concealed weapons is through the use of back-scatter x-ray weapons-detection systems, which use low-dose x-rays to develop images of objects under clothing. The x-rays pass through clothing and are reflected—or “scattered back”—by the skin. These systems have the same limitation as existing portal weapons-detection systems: They require close proximity to detect a weapon. They can, however, reduce the nuisance alarms that occur when metal objects other than weapons are detected and thus move pedestrian traffic more quickly through security checkpoints. In the late 1990s, NIJ launched an aggressive program to find ways to detect concealed weapons from a safe distance. The Institute investigated a wide range of potential solutions—radar, infrared radiation cameras, acoustic devices—and determined that passive millimeter wave (MMW) cameras offered the greatest potential. A passive MMW camera is one that does not use an artificial source of MMW radiation. It develops images from ambient MMW radiation, which, like infrared radiation, is all around but cannot be seen by the human eye.

Although both infrared and MMW radiation can penetrate clothing to develop images of hidden objects, MMW radiation is more effective in this respect. For example, an MMW camera can develop an image through a heavy coat, but an infrared camera cannot. Over the past decade, NIJ has leveraged research and development on MMW technology performed by the U.S. Department of Defense to the point that there now are commercially available MMW weapons-detection cameras. These cameras represent a 10-fold decrease in size and cost from the initial prototypes, but much work remains to be done in improving resolution and range, and reducing weight and cost. NIJ continues to work on developing the potential for MMW technology to detect concealed weapons. For example, the Institute is exploring the use of automobile collision-avoidance MMW radar; and in another project, it is supporting efforts to develop smaller, less expensive MMW cameras. NIJ is also re-examining other technologies, such as infrared cameras, that have advanced in the last decade and could offer new opportunities for the detection of concealed weapons. The new century brings with it new challenges in detecting concealed weapons. As criminal justice professionals work on the technology and protocols to address these challenges, NIJ will continue to provide the research and development that the Federal, State, and local law enforcement communities need to help prevent attacks and ensure the safety of citizens.

Ultrasound is sound that occurs beyond the upper limit of human hearing, 20,000 Hertz (or 20 kilohertz). Ultrasound can reflect off of objects and return to its source, a Property that is used by bats to detect prey. Bats can also use ultrasound to determine Is. Bats use ultrasound in the range of 30 to 200 kHz, An integrated radar and ultrasound sensor, capable of remotely detecting and imaging concealed weapons, is being developed. A modified frequency-agile, mine-detection radar is intended to specify with high probability of detection at ranges of 1 to 10 m which individuals in a moving crowd may be concealing metallic or nonmetallic weapons. Within about 1 to 5 m, the active ultrasound sensor is intended to enable a user to identify a concealed weapon on a moving person with low false-detection rate, achieved through a real-time centimeter-resolution image of the weapon. The goal for sensor fusion is to have the radar acquire concealed weapons at long ranges and seamlessly hand over tracking data to the ultrasound sensor for high-resolution imaging on a video monitor. We have demonstrated centimetre resolution ultrasound images of metallic and non-metallic weapons concealed on a human at ranges over 1 m. Processing of the ultrasound images includes filters for noise, frequency, brightness, and contrast. Frequency-agile radar has been developed by JAYCOR under the U.S. Army Advanced Mine Detection Radar Program. Concealed weapons detector has been built and tested. The Concealed weapons detector will enable law enforcement and security officers to detect metallic and nonmetallic weapons concealed beneath clothing remotely from beyond arm's length to about 20 feet. These detectors may be used to:

(1) allow hands-off, stand-off frisking of suspects for

metallic and nonmetallic weapons; and

(2) search for metallic and nonmetallic weapons on cooperative subjects at courthouse entrances and other monitored security portals. We have demonstrated that we image weapons concealed under heavy clothing, not just detect them, at ranges up to 15 feet using the same ultrasound frequency (40 kHz) used by commercial rangefinders. The concealed weapons detector operates much as a rangefinder, but at higher peak fluxes and pulse repetition frequencies. The detector alerts the user to concealed weapons audibly and visibly by detecting ultrasound glints above a body/clothing baseline, and by compensating for changing range and attenuation. The detector locates concealed weapons within a 6-inch illuminated spot at 10 feet. The signal processor eliminates any signal from behind the target. Detection is that ultrasound does not need the object being examined to be ferromagnetic; It can detect materials regardless of their magnetic properties. It also offers a cost Competitive alternative to x-rays and does not involve ionizing radiation. However, in Order to use ultrasound for such purposes, personnel using ultrasound technology or a Machine equipped to send and receive ultrasound signals must know what to look for in an ultrasound signal that is backscattered off a target. Thus, the main focus of our Experiments was to figure out what part of a return signal contains the data concerning Whether or not the target is armed and how that data can be read and interpreted best. Since the unfortunate events of September 11, 2001, the scientific and security Communities have focused on finding different and accurate ways to detect weapons and Explosives concealed on a person's body. Current technology in that field includes x-rays And metal detectors. In our experiments, we explored using ultrasound as an alternative to these two detection methods. The advantage of ultrasound over magnetic metal detection is that ultrasound does not need the object being examined to be ferromagnetic; it can detect materials regardless of their magnetic properties. It also offers a cost Competitive alternative to x-rays and does not involve ionizing radiation. However, in

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A physical protection system (PPS) integrates people, procedures, and equipment for the protection of assets or facilities against theft, sabotage, or other malevolent human attacks. The design of an effective PPS requires a methodical approach in which the designer weighs the objectives of the PPS against available resources, and then evaluates the proposed design to determine how well it meets the objectives [1].

Metal detection is a physical system, the need of such a system appears for high security, since the evolution of

technology and so many methods appears to detect metals spatially concealed weapons and un authorized devices. Current technology in that field includes x-rays, metal detectors using ultrasound, metal detectors using millimeter wave and metal detectors using magnetic fields. Despite the success of portal type metal detectors based on magnetic fields, commonly found in airports, there remains concern that many weapons still cannot be detected by this means. Examples are ceramic guns and knives, explosives, and inflammables that might be used by terrorist groups to destroy public facilities or to seize and hold hostages. Also, it is not always convenient to require people to pass through a portal for screening, and it is necessary in many instances to look for concealed weapons in crowded situations such as at gatherings where public officials might make appearances. These extra requirements on detestability lead naturally to the necessity for imaging the person or scene of interest so that a trained human observer might judge whether or not a weapon is present. As automatic target recognition techniques improve, this technology will be used to replace the human observer except in cases where verification is needed [2, 3].

## 2. Current Methods

### 2.1. *Weapon Detection Based on Time-Frequency Analysis of Electromagnetic Transient Images*

There is a growing need for effective, quick and reliable security methods and techniques using new screening devices to identify weapon threats. Electromagnetic (EM) weapon detection has been used for many years, but object Many approaches and systems/devices have been proposed and realized for security in airports, railway stations, courts, etc. The fact that most weapons are made of metallic materials makes EM detection methods the most prominent and systems/devices built on the principle of EM induction have been prevalent for many years for the detection of suspicious metallic items carried covertly identification and discrimination capabilities are limited Walk-through metal detectors (WTMDs) and handheld metal detectors (HHMDs) are commonly used as devices for detecting metallic weapons and contraband items using an EM field. Most WTMD and HHMD units use active EM techniques to detect metal objects [4].

Active EM means that the detector sets up a field with a source coil and this field is used to probe the environment. The applied/primary field induces eddy currents in the metal under inspection, which then generate a secondary magnetic field that can be sensed by a detector coil. The rate of decay and the spatial behaviour of the secondary field are determined by the conductivity, magnetic permeability, shape, and size of the target. Sets of measurements can then be taken and used to recover the position, the size and the shape of the objects. Many other EM imaging techniques have been used in WTMDs. These methods include microwave, millimetre waves, terahertz waves, infrared imaging, and X-ray imaging which has been used for luggage

inspections in airports. All these approaches have advantages and disadvantages linked to operating range, material composition of the weapon, penetrability and attenuation factors.

Weapon detection systems currently available are primarily used to detect metal and have a high false alarm rate because they work by adjusting a threshold to discriminate between threat items and personal items, depending on the mass of the object. This leads to an increase in the false alarm level [5].

Also, the human body can affect the sensitivity of the detector as when dealing with low conductivity or small materials, the human body can give a stronger signal than the material. This can cause the material to pass undetected, giving poor reliability. Advanced signal processing algorithms have been used to analyse the magnetic field change generated when a person passes through a portal. Then pattern recognition and classification techniques can be used to calculate the probability that the acquired magnetic signature correlates to a weapon, or whether it is a non-weapon response. Extracting distinct features from the EM signal is imperative for the proper classification of these signals. Feature extraction techniques are transforming the input image into a set of features. In other words, feature extraction is the use of a reduced representation, not a full representation, of an image to solve pattern recognition problems with sufficient accuracy. Extract or generate features from the EM signal is common method for metal detection and classification to represent the possible targets of interest. Feature extraction using Time-Frequency analysis has been used for stationary targets of backscattered signal. Features are extracted from scattered field of a given candidate target from the joint time-frequency plane to obtain a single characteristic feature vector that can effectively represent the target of concern. Joint time frequency analysis was used to overcome the limitation of using the Fourier transform (FT) series to represent the EM signals which is require an infinite number of sinusoid functions. The sinusoid function provides a feasible way of computing the power spectrum for EM signal, which is serves as unique fingerprint of the weapon detection response to various targets, i.e., weapons, cell phones, etc. The literature review revealed that wavelet transform (WT) are a successful method for the signal representation of time series data such as EM signals. WT has been used to represent time series data such as ECG waveforms and mine signal detection. The WT can be thought of as an extension of the classic FT except operating on a multi-resolution basis. The results obtained from verify that the WT based technique produces features that are suitable for detect and identify metallic targets signal data. After Feature extraction step, the images can be displayed for operator-assisted weapon detection or fed into a weapon detection module for automated weapon detection and classification. In, authors present an artificial neural network (ANN)-based scheme for metal target detection and classification. The proposed strategy involved the use of various neural networks schemes for performing

feature extraction and classification tasks. It was shown that the use of an ANN in multispectral wavelengths provided a useful tool for target detection and classification. In a case study on classifying metal detector signal for automated target discrimination is conducted. In this research an adaptive resonance theory networks was used and the results indicate that ANN has a vital role to improve the performance of classification. In, probabilistic ANN classifier used to classifies the extracted weapon candidate regions into threat and non-threat objects. The proposed framework is evaluated on a perfect database consisting of various weapons in different size, type of gun and real images and 96.48% accuracy rate has been obtained., the ANN used to differentiate between different target types such as a Glock or a starter pistol. A combination of techniques is presented that enables handguns to be effectively detected at standoff distances. Late time responses that allow threat from innocent objects (e.g., mobile phones, keys, etc.) to be distinguished from handguns. Information about the optical depth separation of the scattering corners, and the degree and shape of cross polarization allows ANN to successfully detect handguns in that research. Support Vector Machine (SVM) has been used recently as a new machine learning methods. SVM is a concept in statistics and computer science for a set of related supervised learning methods that analyse data and recognize patterns, used for classification and regression analysis., the authors revisit an attractively simple model for EM induction response of a metallic object using SVM to train and produce reliable gross characterization of objects based on the inferred tensor elements as discriminators. They focusing on gross shape and especially size to evaluate the classification success of different SVM formulations for different kinds of objects, and noticed that SVM has an inherent limitation that it takes a very long time to yield an answer in some instances, the problem of classification metallic objects using their EM induction response is solved by decomposing that response into coefficients and then using SVM and ANN to process those coefficients. The performance of each method is compared. Since it demonstrate that there is no simple relationship between sizes of objects and the overall magnitude of their coefficients, learning algorithms are necessary and useful in classifying these objects. When trained on all types of objects, both the ANN and the SVM are able to classify all objects with a good degree of accuracy. In addition, both methods show an ability to generalize for noisy test data when trained with noisy data. A new detection system developed at Newcastle University and built in a lab using an ex-service CEIA WTMD, with the addition of a Giant Magneto-Resistive (GMR) sensor array to capture the EM scattered data from any metallic objects, is used in this study.

The contributions of this paper are: firstly, improve the characterization capabilities of the new detection system through investigation of the effect of different orientations as well as the effect of concealed weapons. Secondly, investigate the feasibility of extraction features from WT and FT for weapon detection. Thirdly, automatically recognize

and classify metallic threat objects by using of Support Vector Machine (SVM) and Artificial Neural Network (ANN) as classifiers.

## **2.2. DWT Based Image Fusion for Concealed Weapon Detection**

A variety of approaches to concealed objects detection on the human body based on magnetic, acoustic or ultrasound, electromagnetic resonances based target recognition, and image processing technologies have been developed. In the image processing technology, image is acquired by the THz, infrared, x-ray or millimetre wave imaging system. Image fusion has been identified as a key technology to achieve improved CWD procedures. Image fusion is a process of combining complementary information from multiple sensor images to generate a single image that contains a more accurate description of the scene than any of the individual images [4]. The result of image fusion is a new image which is more suitable for human and machine perception or further image processing tasks such as segmentation, feature extraction and object recognition. Multi resolution analysis plays an important role in image processing, it provides a technique to decompose an image and extract information [4].

Imaging Sensors THz Imager Tera view is the first commercialized tera hertz imaging system using a short pulse as the waveform. Two methods can be used to generate THz based on electronics and photonics. For the photonic method, the femto-second laser TDS systems are very popular. THz can be generated by mixing of two laser frequencies in a photo conducting antenna. Systems of this kind are compact and less expensive than femto second laser systems. The electronic approach is to use electronic component such as Scotty-barrier diode (SBD), super-conductor insulator superconductor (SIS) and hot electron bolometer (HEB) mixers as the heterodyne detectors. One disadvantage of using the electronic approach to generate THz signals is the limited output power which is not suitable for standoff detection. Since metals, ceramic guns and knives, clothes and human skin gives different level of reflection in the THz band, THz pulsed imager can be used for security screening. THz based CWD has the advantages of high resolution, wide THz spectra, and uses no ionizing radiation to illuminate human body. The system is transportable, both metals and non-metals can be detected. While THz provides high resolution, it has the drawbacks of high atmospheric absorption and is limited to operation close to the target.

The Infrared Imager operating principle of an infrared imager is based on the detection of thermal radiation difference from the target space. Infrared detection of concealed weapons or dangerous contraband materialises essentially a function of the temperature difference between the object and the human body. Infrared imaging has a few drawbacks when used forced operations. Firstly, the wavelengths in infrared band are too short to penetrate clothes. Assuming the clothing is tight, the radiation from the human body heats the clothes and the radiation is reemitted

which would make the target image blurred. For loosely wearing clothes, it would be even more difficult forced operation as the human body radiation would be spread over large area. Secondly, when the temperature of the concealed target approaches that of the human body, which is likely to occur when the target is concealed in the body for a long time, detection would be difficult. Infrared technology based imagers are passive and transportable and portable.

Stand-off operation is possible. Both metals and non-metals can be detected. But it has the drawbacks of low penetration ability to clothing and no differentiation (assuming emissivity is the same) for targets with the same temperature.

The X-ray Imager first commercially viable CT scanner was invented by Sir Godfrey Hounsfield in Hayes, United Kingdom at EMI Central Research Laboratories using x-rays. Hounsfield conceived his idea in 1967. The theory of operation for x-rays imager can be explained by the Compton Effect. X-ray imagers are an active system. The system is generally large in size but transportable and it is close range detection. Both metals and non-metals can be detected. It has advantages of high resolution, high penetration ability. Scanning speed of commercially available x ray imagers is high enough, a few seconds per scan. The drawbacks of the x-ray imaging for a human body are that it contains anatomical information of human body, it raises the privacy issue. There may be a safety concern because x-ray radiation is ionizing, even though the dosage is much below the level that the authority believes is safe, public acceptance thus an issue.

### **2.3. Handheld Ultrasonic Concealed Weapon Detector**

A hand-held ultrasonic device capable of concealed weapon detection for use by law enforcement and security personnel. Under contract to the National Institute of Justice (NIJ), 20 second-generation units are being fabricated for delivery and evaluation to their Force Research Laboratory in Rome, NY. The second-generation units are based on the technology developed under previous effort that resulted in the production of several prototype handheld units that were shown to be effective at detecting both metallic and non-metallic concealed weapons at distances up to 12 feet. As a result of that successful prototype development program, a follow-on effort for enhancing the detector's ability to see through a wider range of clothing material types was initiated. The initial prototype detector was somewhat limited as to its ability to see through heavy clothing such as leather jackets and winter parkas which have a relatively high reflectance for the ultrasound waves emitted by the device. The second generation units have been modified with higher output power transducers and more sensitive detection circuitry to enable better clothing penetration while at the same time allowing for an extended range of detection out to 25 feet. Due to the inherently high reflectivity of ultrasound energy from leather and other heavy or tightly knit synthetic materials, the device is most effective when viewing objects under woven materials such as sweatshirts, sweaters, wool suit coats and the like. Applications of this concealed weapon

detector (CWD) include remote pat-downs by law enforcement (LE) officers before moving in to do a hands-on search that would still be required. As such, the detector could provide probable cause. For performing a more intensive search of a suspect. In addition, simply pointing the detector at a suspect can elicit behaviour archangels that an experienced officer could observe. It is important to note that this detector can't tell the difference between a weapon and an ordinary object such as a cell phone, a bunch of keys, credit cards etc. which can all trigger false alarms. However, our philosophy has been that a false alarm from a harmless item is preferable to not being able to detect a potentially dangerous weapon. Under the current effort, we have improved the signal processing of the device to lower the false-alarm rate and also increased the probability of weapon detection through heavy clothing. Product availability will depend to a large degree on the outcome of this upgrade effort and subsequent evaluation by the government. We presently see these devices becoming commercially available in the early 2003 time frame with a projected price of less than \$500. The ultimate goal is an affordable, hand-held, standoff weapon detection device.

Concealed weapon detector concept the hand-held detector is an outgrowth of a more complex sensor design that was capable of imaging concealed weapons. The first-generation prototypes of the hand-held unit, dubbed the CWD-2000, were designed to simply detect (yes/no), rather than image, concealed weapons up to a range of about 12 feet. The detector operates in much the same way as commercial range finder, but at higher peak acoustic intensities and higher repetition rates. The detector alerts the user to the presence of a concealed object using an audible tone and a visible light-bar indicator.

On-board receiver electronics monitor ultrasound glints above a body/clothing background level while compensating for changing range and attenuation. Photograph of one of the first generation CWD-2000 prototype units

#### *CWD Features and Technical Specifications*

The prototype CWD-2000 has a number of operating features that have been carried over into the second-generation (CWD-2002) units. Both units utilize a single 40-kHz ultrasonic transceiver. The CWD-2000 can detect concealed weapons (either metallic or non-metallic) at distances up to 12 feet away through a limited set of clothing material types on a stationary individual. The ultrasonic beam pattern of the detector is a circular spot about 7 to 12 inches in diameter at ranges from about 3 to 12 feet. The CWD-2000 units work reasonably well at finding objects between 3 to 12 feet in front of the detector, with the highest probability of detection from 4 to 7 feet. It does not work at all closer than about 3 feet due to a range-gating feature that isolates the sensitive receiver electronics from the large transmit pulse. This feature has also been carried over into the CWD-2002 units. With a modified transmit drive circuitry and increased sensitivity on the receive electronics, the CWD-2002 units can detect concealed objects out to 25 feet. In operation, the detector should be aimed first at areas

of clothing where weapons are likely to be concealed, including, of course, any obvious bulges in clothing. Once pointed at an area, the detector is then moved from side to side and up and down, using the aiming light to keep the detector pointed at the spot of interest. The side to side and up and down motion of the detector allows it to view the spot from a wider range of angles, increasing the probability of detection. As the user inspects the suspect, when an alarm sounds, the user should then return to the area that produced the alarm and concentrate a search there to determine the view angle that gives the strongest alarm. Level 4 or 5 alarms (as shown on the LED light bar) are strong indications of a concealed object. For precise aiming, a focussed 5-W halogen lamp allow the user to determine where on a person the detector is pointed. As a side benefit for law enforcement, the high-intensity light canals be used as a spotlight or to temporarily disorient a suspect. We have incorporated a low power laser pointer as an aiming light into the CWD-2002 units to allow for more covert operation. This feature also allows for operation off a single battery pack which reduces the weight of the handheld unit. In the CWD-2000 units, the detector and aiming light circuitry are powered by separate battery packs. An audible alarm, normally heard through the rear-mounted speaker, can be optionally heard using an earphone jack that mutes the speaker when in use. An adjustable knob on the back of the detector controls the loudness of the speaker and earphone. The tone is designed to increase in pitch and intensity as a function of increasing received signal level. A visible alarm indicator in the form of a 5-level light bar on the back of the detector housing shows the relative intensity of the received signal. The lowest level is used as a power ON indicator (with trigger pressed). The detector is designed to look for concealed weapons as long as the trigger is pressed. All of these alarm features have been carried over into the CWD-2002 units.

Second-Generation Upgrade Activities there were four upgrade activities pursued for the second-generation units under the current effort. The results of these activities have been assessed and incorporated, where feasible, into the upgraded design. At the end of the current effort, 20 functional CWD-2002 units will have been fabricated, tested and delivered to AFRL for further field-testing and evaluation. A brief description of the four upgrades activities and the results of each follow.

Multiple transducers With both the initial CWD-2000 design and the CWD-2002, the user must move the detector from side to side and up and down while focussing on a fixed spot to maximize the viewing angle of the detector and thus increase the probability of detection. This is a result of the relatively narrow field of view (FOV) of the detector/antenna configuration (3-5 degrees).

The narrow FOV is necessary to have a spatial resolution on the order of 6 inches (a typical handgun or knife dimension) at a range of 12 feet. If the reflected acoustic energy is not within the FOV, the detector can be pointed at a concealed item and not see it. Fortunately, most weapons, like handguns, have multiple facets that generate their own

secular reflection.

A 5-inch diameter parabolic dish is used to collimate the diverging ultrasound beam source. The effective full-width-at-half maximum (FWHM) transmitted intensity was measured to be 3.0 degrees. This divergence, while small, corresponds to an effective field of view of about 7. on a target at 12 feet range. Thus, the small divergence gives an unacceptable spot size at the desired range but also limits the sensitivity of the detector to off-axis glint angles. At the extended range of 25 feet, the lateral extent of the FOV for the CWD-2002 is about 17 inches.

This glint angle sensitivity affects the probability of detection, PD, because of the chance that the detector will not irradiate facet of the weapon at near normal incidence (within the FOV of the detector). Since most concealed weapons, like handguns or knives, are carried flat against the body, the best angle for aiming the detector at each spot, therefore, is normal to the body surface. Presently, the most effective way to use the detector is to aim it at locations on the body where weapons are likely to be concealed, and then use lateral and vertical motions of the arm to cover a range of angles about the normal while aiming at the same spot.

Since the range of angles of incidence of the ultrasound beam on a suspect is limited, it becomes harder to detect objects with increasing range. To alleviate this problem, i.e., to increase the probability of detection, the use of additional transducers was thought to have the potential for effectively increasing the FOV of the detector while maintaining the desired spatial resolution. We installed additional ultrasound transmitters around the periphery of the existing cylindrical shield cage using two and then four separate transmitters to determine if this approach would be effective. To increase the effective viewing angle even further, a folding support arm for each transducer was also examined. For example, using a 4-inch radial extension arm for each transducer would theoretically increase the viewing angle from the current 3 degrees to about 9 degrees. These additional transducers were not collimated (only the central transmitter was collimated), so their beam patterns were on the order of 3 to 4 feet in lateral extent at distances beyond 10 feet. However, since the receiver was still in a collimated configuration, i.e., looking at a spot on the order of 6 inches diameter, there was little observed interference from reflections outside the existing FOV. The effect is analogous to viewing an object with a microscope and using additional side lighting for increased illumination. There were two problems encountered with these configurations that eventually determined that the addition of extra transmitters was not useful in increasing PD. First, due to the large divergence of the peripheral transmitters, the power on target (within the field of view) was relatively small when compared to the power being delivered by the collimated co-axial source. Thus, the central collimated source tended to dominate any reflected signal, minimizing the advantage of the additional illumination. Without using rather large and cumbersome collimators on these peripheral transmitters, this approach did not yield any significant increase in the effective field of view. Secondly,

there was a problem with constructive and destructive interference between the different transmitters that resulted in erroneous readings when viewing an object at slightly different angles.

Dynamic detection threshold in order to enhance the signal-to-noise (or signal-to-clutter) ratio, for a given set of conditions (range, weapon type, and clothing type), a variable or dynamic detection threshold setting is being considered. In the present design, the threshold for detection is factory set. For an unarmed person wearing a light cotton shirt standing at a range of about 7 feet. For these conditions, only one light (that also serves as the power ON light) on the 5-light LED display is illuminated. The disadvantage of a fixed threshold setting is that for clothing materials with an above-average reflectivity, the total dynamic range of the detector is not utilized and there is a tendency for the number of false-positive alarms to increase. A dynamic, or variable, detection threshold setting will allow the sensor to adjust its sensitivity according to the type of clothing a suspect is wearing. Operationally, the user would point the detector at several different areas on the suspect (both front and back as the suspect is directed to turn around slowly) and the light bar indicator would show the readings for each area while preserving the dynamic range of the detector. The circuitry for an active or dynamic threshold for detection is being designed to sense the average level of reflectance and automatically adjust the low end of the detector to compensate for clothing materials with an above average reflectance. Thus, the dynamic threshold circuit adjusts the zero-level of reflectance in order to preserve the dynamic range of the detector. The net effect will be an increased probability of detection. This function will be implemented as part of the analog processing electronics in the CWD-2002 units.

Use of multiple and/or different frequencies the use of ultrasonic frequencies other than 40 kHz was also examined under the current effort. Higher frequencies are able to resolve an object's spatial location more precisely, whereas lower frequencies are able to better penetrate through clothing more readily. A 60 kHz transducer was examined but found to have too high attenuation (about 2.3 dB/m) in air and not enough initial drive power to be useful. A configuration using two transducers with one operating at 40 kHz and the other at 23 kHz was also examined in the hope that increased detectability could be achieved by allowing the 20-kHz energy to better penetrate and detect an object (although with diminished spatial resolution). Using the same collimating optics as in the CWD-2000, the spatial resolution at 23 kHz was found to be on the order of 10 inches at a range of 10-12 feet. The disadvantage of using two separate frequencies is that it requires a more complicated focusing/collimating configuration since the two sources need to be coaxial or have different, and bulkier, collimating optics. Also, the 23 kHz transducers were much bigger than the 40 kHz elements and did not seem to provide for any significant increase in PD.

Signal-Shape Discrimination A fourth approach that was

considered involved data processing of the return (reflected) signal. During previous efforts, it had been noted that the return pulse is sometimes characterized by a waveform that is dependent upon the shape of the object being detected. With the existing CWD-2000 units, motion of the handheld unit over a target spot also results in temporal changes to return signals, particularly if a hard, reflecting object is present in the target region. After a series of measurements on a variety of two-dimensional targets of different shapes (square, circle, elongated rectangle, etc.) no consistently discernible differences in waveform signature relative to target shape were observed [9].

#### ***2.4. Radio-Frequency Measurement System for Metallic Object Detection Using Pulse Modulation Excitation***

We are in this section going investigation of RF measurement for metallic object detection using pulse modulation excitation which consists of multiple frequency harmonics with the centre frequency varying within 1-12 GHz. The frequency response and resonance frequency behaviour of object position, object shape, rotation and multiple objects have been tested and analysed. A system utilising the pulse-modulated RF mode and sweep-frequency mode has been set up to implement sensing of metal items at a standoff distance more than 1 meter. Through a series of experimental investigations, it can be found that the positions of the metal items have significant effect on the spectrum profiles of received RF signals. Such effect presents a modulation pattern in frequency domain, in consequence of which new features have been investigated in order to implement detection and characterisation of metallic objects.[10]

#### ***2.5. Detection of Concealed Weapon in X-ray Images Using Fuzzy K\_NN***

X-ray imaging is an important technology in many fields from inspection of delicate objects to weapon detection at security checkpoints. To achieve higher threat detection rates during inspection of X-ray luggage scans is a pressing and sought after goal for airport security personnel. The Baggage inspection system used in airport ensures security of the passengers. The process of identifying the contents of each bag and the methods adopted by terrorists for hiding the threat objects are complicated, the existing luggage inspection system do not reveal 100% of threat items. Further an object inside a bag may be in any position, it may be rotated so an algorithm which is rotational, translational invariant should be used for providing accurate results. In addition, the threat item is superimposed by other objects in the bag, the harder it becomes to detect it (effect of superposition). The passenger's baggage may contain threat items such as handgun, bomb, grenade, etc which must be detected efficiently so the human operators must be assisted by an weapon detection system. Advanced security screening systems are becoming increasingly used to aid airport screeners in detecting potential threat items. Unfortunately,

most airport screening is still based on the manual detection of potential threat objects by human experts. In response to this, security training is relying heavily on the object recognition test (ORT) as a means of qualifying human airport luggage screeners. In order to provide appropriate security, a much more sophisticated, reliable, and fast screening technique is needed for passenger identification and baggage examination. Automatic threat detection is an important application in x-ray scene analysis. Understanding x-ray images is a challenging task in computer. Although several X-ray technology based automatic systems exist for threats detection, only a few of these systems make use of the well established pattern recognition and machine learning techniques. On the other hand, several approaches based on Classifier have been proposed to detect weapons. Additionally, the importance of image enhancement and pseudo colouring to help aid decision making by human is now a recognized area of critical need. Also, the system should provide automatic detection of potential threat objects.[11].

### ***2.6. Privacy Algorithm for Cylindrical Holographic Weapons Surveillance System***

A novel personnel surveillance system has been developed to detect and identify threatening objects, which are undetectable by metal detectors, concealed on the human body. This new system can detect threats, which are fabricated with plastic, liquid, metal, or ceramic. It uses millimetre-wave array technology and a cylindrical holographic imaging algorithm to provide full-body, 360-degree coverage of a person in near real-time. This system is ideally suited for mass transportation centres such as airport checkpoints that require high throughput rates and full coverage.

Research and development efforts are underway to produce a privacy algorithm that removes the human features from the images while identifying the potential threats. This algorithm locates and segments the threats and places them on a wire-frame humanoid representation. The research areas for this algorithm development include artificial neural networks, image processing, edge detection, and dielectric measurements. This system is operational and results from this test and the privacy algorithm will be discussed in this paper.

The technology employed in the cylindrical holographic image system (CHIS) includes a millimetre-wave (MM-wave) transceiver and array, high-speed digital signal processing computer, cylindrical scanner, and a cylindrical holographic imaging algorithm. Because millimeter waves are, unlike x-rays, non-ionizing and therefore pose minimal health risks, they are ideally suited for surveillance of people. The array illuminates the person under surveillance with very low power millimeter waves, which readily penetrate clothing barriers and reflect off the body and concealed threats. These reflected signals are collected by the array and sent to a high-speed imaging- processing computer where they are formed into very high-resolution radar images by the

cylindrical holographic imaging software. After the cylindrical holographic images are formed, they are sent to a video monitor where the system operator can detect and identify the concealed threats. Although this security system can detect and identify non-conventional concealed threats, it also displays human physical features in the imagery. This delayed the full testing and implementation of this new scanning technology into airport checkpoints. There is a perceived public opinion that directly presenting the imagery data to the operator would be unacceptable because of personal privacy concerns. It is believed that public acceptance of this type of screening system would likely be greater if the imagery was presented to a computer pattern recognition or segmentation algorithm for threat detection and identification rather than to a human operator. In this scenario, the operator would be retained in the security activity to clear the alarms generated by the privacy algorithm from either false positives or real threats. In 1997, work was initiated on a privacy algorithm for the CHIS with the near-term goal of developing software techniques to automatically segment concealed threats and innocuous items from the imagery and place these objects on a generic facsimile of a human. The ultimate goal for the privacy algorithm is to eliminate from the imagery all human features that may be considered too intrusive. This paper details the initial privacy algorithm development and laboratory testing.

Several techniques were applied to partially automate the detection of weapons in the imagery obtained from the CHIS system. All of these techniques are based on segmenting suspicious areas of the images and placing them on a wire-frame or optical video image of the person being scanned. This would alleviate privacy concerns by precluding the showing of the body parts of the person being scanned; instead, showing only detected items. The three segmenting techniques discussed in this paper, along with the results from this work [11].

### ***2.7. Privacy Algorithm for Cylindrical Holographic Weapons Surveillance System***

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- automation by using 3-D image depth information to segment suspicious areas for placement on optical video image or wire-frame model;
- automation by using pattern/texture recognition or segmentation schemes of the cylinder and mannequin data; and

- automation by using dielectric measurements to segment suspicious areas.

Additionally, this paper discusses work that was performed on the presentation techniques to the system operator that eliminate human features obtained in the MM-wave [11].

### **2.8. Millimetre Wave Technology and Image Fusion Algorithm**

Concealed weapon detection (CWD) has been necessary as the concern about public safety increases. There have been a series of attacks dating back to March 1993, the terrorist bomb, causing enormous loss of property and human lives. The public transportation system and gathering places attracted most of the interests from the terrorists because of its economic significance and the influence that the terrorists can exert through it. In the US, the Transportation Security Administration (TSA) provided its National Research Council (NRC) with following statement of task:

1. Identify potential applications for technology in transportation security with a focus on likely threats;
2. Evaluate technology approaches to threat detection, effect mitigation, and consequence management.
3. Assess the need for research, development and deployment to enable implementation of new security technologies.

The introduction of computed tomography based on x-ray to the airport check in procedure for the passenger luggage has improved the security, however, for the passengers; security check still relies on the hand held and portal-style metal detectors assisted by human stop and search. There are drawbacks for this type of detectors, and the weaknesses can be exploited by the sophisticated terrorists. The public and authority call for complex and comprehensive security systems. A variety of approaches to concealed objects detection on the human body based on magnetic, acoustic or ultrasound, electromagnetic resonances based target recognition, and image processing technology technologies have been suggested and developed. In the image processing technology, image is acquired by the THz, infrared, x-ray and microwave or millimeter wave imaging system. Image acquired by these imaging system have noise. Denoising is applied to improve the quality of the acquired images and enhancement of the image. After denoising and enhancement, weapon detection technique is applied, and finally concealed weapon is detected.

### **2.9. Terahertz Illuminator with an Un Cooled Imager**

Two THz-imager architectures based on incoherent and coherent detection were under consideration for achieving the program objectives. Both schemes have advantages but differ in complexity.

In an incoherent architecture, a THz beam illuminates the object and the backscattered THz signal is focused by the optics onto a THz detector array. A lens at the output of the THz source, possibly designed as zone plate to enable zoom functions, allows for optimal object illumination within areas

of 60 cm and 20 cm diameter at approximately 10 m and 3 m standoff distance, respectively. The imaging optics consists of at least two lenses to achieve good spatial resolution across the image in the focal plane.

In a coherent architecture, the backscattered light is detected by superposing it with a reference beam that possesses a fixed frequency relation to the backscattered light. Although a coherent detector would gain about a factor of  $\sim 40$  in sensitivity, such architecture is currently infeasible, the project experience shows that commercially available THz components are not mature enough to be integrated into reliable coherent imaging schemes. In both architectures the illuminating beam would be 100% intensity modulated to enable lock-in amplification on the detector side and background noise suppression.

Several different objectives that can be combined with incoherent or coherent imager technology were analyzed. We selected a two lenses Fresnel optics and a CASs grain type reflector as objectives for the experimental phase of the development. Both optics' have intrinsic advantages with respect to several product relevant aspects e.g. low cost, low loss, and compact size.

A literature search and discussions with law enforcement were used to develop preliminary performance specifications that would satisfy the needs of various customers. As a THz imager is a novel device, potential customers have not precisely determined the best trade off between imager performance and SWAP (Size, Weight, and Power). The imager's aperture and spatial resolution are related through fundamental optics principles. A small aperture lowers the spatial resolution and therefore the image quality. While the required standoff operation distance is reasonably well established, parameters describing the required imaging quality in terms of gray-scale resolution, spatial resolution, and size are not readily available. Detection of concealed weapons up to 10 m distance would be of high value and would cover several applications. A 60 cm field of view at 10 m distance would allow for efficient screening of a standing suspect's cross section by pivoting the imager in a vertical scanning motion. At 3 m distance the field of view is about 20 cm in diameter, large enough to image handgun. The specified spatial resolution requires about 60 detector pixels along the diameter of the THz image.

The power budget of the imaging system was estimated by assuming 0.5 dB loss per lens, 1 dB propagation loss in 10 m air, 32 dB scattered light attenuation at 10 m distance for a 500 mm aperture optics, 35 dB power splitting loss per pixel, and required minimum illumination power of 640 pW per pixel to achieve 4-bit grayscale resolution at video frame rates (detector NEP  $\sim 10 \text{ pW}/\sqrt{\text{Hz}}$ ). A THz source with 10 mW output power would be sufficient to record images of weapons carried under shirts ( $\sim 1$  dB loss) at 10 m distance.

The weight of the imager head should be less 10 kg so that it can be attached to the operator's body (backpack). With our developed lenses we are approaching a weight. The over

methods were used to detect the weapons are shown in table.

### 3. Conclusion

The paper can give over all information regards the concealed weapon detection system using several techniques which was explain. Finally the work can give advantage and disadvantage for each method of detection system.

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### References

- [1] Mary lean Garcia The Design And Evolution of physical protection systems, amoretepederesn (2007).
- [2] McMillan, R. W.; US Air Force Res. Lab., Rome, NY, USA; Currie, N. C.; Ferris, D. D., Jr.; Wicks, M. C. Concealed weapon detection using microwave and millimetre wave sensors, proceeding of Microwave and Millimetre Wave Technology Proceedings, (1998) Beijing.
- [3] John Edward DuChateau, Using Ultrasound in Concealed Weapons Detection 2005.
- [4] N. G. Palter, "Users' Guide for Hand-Held and Walk-Through Metal Detectors", NIJ Guide 600-00, NCJ 184433, Office of Science and Technology, U.S. Department of Justice, Washington, DC 20531, 2001.
- [5] H. M. Chen, S. Lee, R. M. Rae, M. Shamanic, and P. K. Varshney, "Imaging for Concealed Weapon Detection", IEEE Signal Processing Magazine, Vol. 22, pp. 52-61, 2005.
- [6] Abdurrahman Al-Cuba and Guy Yen Tina "Weapon Detection and Classification Based on Time-Frequency Analysis of Electromagnetic Transient Images" School of Electrical, Electronic and Computer Engineering Newcastle University, Newcastle upon Tyne, NE1 7RU, UK.
- [7] C. Y. Went, J. K., "Chen Multi-resolution image fusion technique and its application to forensic science" ELSEVIER, November 2003.
- [8] Dinar Rae Dongle\*, VidhiRawat\*\* and Abhishek Rawat\* "DWT Based Image Fusion for Concealed Weapon Detection" \*Department of Electronics and Communication Engineering, Sam rat Ashok Technological Institute, Vinita (MP), India. \*\*Department of Biomedical Engineering, Sam rat Ashok Technological Institute, Vinita (MP), India.
- [9] Y. Li and G. Y. Tian, "A Radio-frequency Measurement System for Metallic Object Detection Using Pulse Modulation Excitation," pp. 25-28, 2008.
- [10] J. T. Banks and E. T. Al, "D Etection of C Erebrospinal F Luid S Hunt or," vol. 57, no. 6, pp. 1237-1243, 2005.
- [11] P. E. Keller, D. L. McMakin, D. M. Sheen, A. D. McKinnon, and J. W. Summet, "Privacy Algorithm for Cylindrical Holographic Weapons Surveillance System," 33 rd Annu. IEEE Conf. Secur. Technol., vol. 15, no. 2, pp. 17-24, 2000.
- [12] Standoff Detection of Concealed Weapons using Terahertz Illuminator with an Uncooled Imager NIJ Award: 2007-RG-CX-K013.