

A STUDY REPORT ON X-RAY SENSOR AMPLIFIER PCB FOR X-RAY BAGGAGE INSPECTION SYSTEM (XBIS)

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Abstract

Security is one of the key aspects for public safety. Packages and luggage should be examined for weapons, narcotics and explosive devices by security system to ensure safety at places like airports, parliament house, banks, etc. One such system is X-ray Baggage Inspection System (XBIS). An X-ray generator supplies required radiation during screening and emitted X-rays penetrate through object under examination while passing through unit. Screening of luggage is done slice by slice and hence obtained picture information is then stored, processed to an extraordinary clear, informative complete image and finally reproduced on monitor screen. X-ray TV image generated in accordance with scanning principle where item of luggage is routed past linear detector line by means of conveyor belt. This detector line consists of X-ray sensor amplifiers mounted on PCBs. This project deals with design of X-ray sensor amplifiers. At detector side of XBIS set of X-ray sensor amplifiers on PCBs are arranged in horizontal and vertical lines on another side of X-ray generator. Two sets of 16 PCBs are arranged one above other in two layers for lower and higher energy perception. Diodes in a line are scanned by incrementing the address also the object is screened line-by-line as it moves on conveyor belt. Hence obtained picture information on screen presents information of objects and its inner parts taking advantage of penetration of X-rays through the objects.

Keywords-- XBIS, Sensors, Line Scanning & Lamps

1. INTRODUCTION

In olden days, the security system in the country was very liberal. There was least threat to the security of defence installation and some important places like VVIP residences. Only authorized persons had access to these places. At airports[3] the luggage of passengers were opened and checked manually. The number of travelers then was less and this process of checking the luggage was easy. But with the increase of travelers, increase in smuggling of arms and narcotic products, there arose a need to modernize the security system. Thus luggage - scanning system was developed. The manual checking process is time consuming, tedious and fatigue to security personnel. In order to ease this process the X-ray Baggage Inspection System (XBIS) was introduced.

XBIS is used to screen the luggage or cargo for security defence installation. The XBIS system is compact system using X-rays for the quick and efficient examination of handbags, parcels, suitcases etc. The unit is equipped with a conveyor belt, which acts as a transport tunnel. The screening elements can be differentiated based on density and colour. If any suspicious things are detected in the luggage, then it will be manually checked. This system maintains privacy of person's luggage.

XBIS is optimal for the usage in a public place. Packages and luggage can be examined for weapons, narcotics, explosive devices or other illegal contents without precautionary measures. For repeated exposures, it does not face any radiation dosage threat to the operation personnel or the general public, which conventional system would need to ensure public safety. A simplified, yet, safe operation has been successfully mated with a highly sophisticated screening technology, which provides extremely high image quality.

2. X-RAY BAGGAGE INSPECTION SYSTEM(XBIS)

X-ray scanning procedure works on principle of penetrating X-rays on bag or luggage to be detected. X-ray scan distinguishes objects by their atomic number and classifies by colour.

XBIS contains following major sub assemblies: X-ray generator, X-ray sensor amplifier PCB, Computer with software, Tunnel with a conveyor mechanism through which the baggage passes through Image processing software with display and keyboard



Fig 1: X-ray Baggage Inspection System[5]

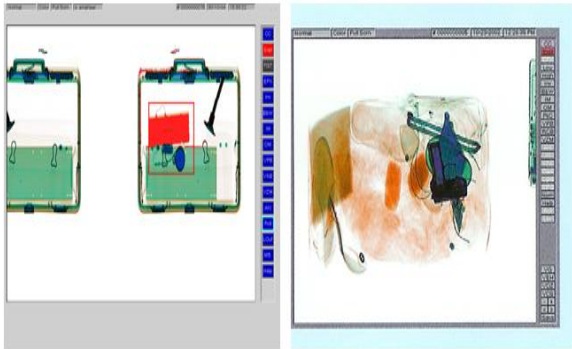


Fig 2: Baggage Seen on Screen[5]

X-Ray Generator: X-ray generator consists of X-ray tube, filament transformer, and high voltage multiplier stack on PCB with transformers giving +70kV and -70kV. Generator internal components are immersed in mineral transformer oil. There are bellows at one end of generator to allow for expansion of oil. A primary collimator is adjusted to provide a thin fan beam of X-rays[2]. A second collimator is fitted to underside of X-ray machine conveyor belt on smaller machines. The function of this collimator is to reduce the scattering of X-rays inside the tunnel.

Conveyor Belt: X-ray machines have flexible conveyor belt driven by drive roller at exit end of conveyor belt. The drive roller consists of a motor that rotates a drum at output end of the belt. Motor is driven by main ac supply and has two windings namely, auxiliary winding and main winding. Auxiliary winding keeps motor rotating in correct direction. Main winding supplies power. Drive roller must be in correct position because it may have no torque, run in wrong direction, blow its fuse, overheat, or simply not run if wiring is incorrect. Motor start capacitors are used to operate drive roller.

Motor: X-ray machine has chain driven rollers powered by three phase motors. The three phase motor is powered by three phase supply or single phase converted to three phase by inverter. Inverter has 230V ac input, so step up transformer is required if line voltage is 115V. Rollers run at 0.1m/sec or 0.2m/sec.

Power Supplies: Two types of power supplies are used in the scan system. It contains two switched mode power supplies and the X-ray head power supply, which is custom-wired. One switched mode power supply is used for X-ray Sensor

Amplifier PCBs to avoid any glitches caused by motors, as boards are sensitive. Other switched mode power supply is used for motor drive circuitry on main control PCB and illuminate lights at the end of the tunnel.

Main power supply 220V a.c. input, +12V and +5V DC output

X-ray sensor amplifier power supply 220V a.c. input, +15V and +5V DC output

X-ray head power supply generates 65V DC unregulated, 12V DC regulated and is fed to X-ray control PCB.

Infrared Sensors: Its function is to detect presence of object at known points within the tunnel. There are three types of sensors in use.

Through Beam Sensors: It consists of PCB assemblies, which contains a row of three IR transmitters and other a row of receivers and associated circuitry. These are mounted one each side of tunnel. Transmitter unit has a red LED next to the cable entry, when it is illuminated it indicates that supply is present. Receiver unit also has a red LED next to the cable entry, when it is illuminated this indicates that supply is present and that beam is made. Breaking the beam will cause LED to extinguish.

Reflective Sensors: They consist of transmitter/receiver unit and a reflector. Reflector is mounted opposite side of tunnel to transmitter/receiver unit. Device has a bi colour LED that shows green when the beam is made and red when broken. If it is unlit, then supply is not connected

UDT3 Through Beam Sensors: Units are mounted one each side of the tunnel. Transmitter unit has three clear LEDs next to cable entry. Receiver unit has three green LEDs next to cable entry; each of them, when illuminated indicates that supply is present and that beam is made.

Control Panel: The control panel consists of rectangular box containing membrane panel or push button switches and LEDs mounted on a PCB, and a cable. Its purpose is to encode key presses and transmit codes to the computer. The computer interprets the codes and acts accordingly. The control panel also receives codes from the computer to establish that the communication link is functioning correctly and to instruct the PCB to illuminate the various LED indicators.

Video Monitors: Two video monitors are supplied with the system. One is monochrome and other is a Super Video Graphic Adapter (SVGA) monitor. Monochrome monitor is operated at 50Hz and SVGA monitor can be operated at 640*480, 800*600, 1024*786 or 1152*864 non-interlaced mode. There are controls for colour, contrast, brightness, height, vertical shift, width, horizontal shift, tilt etc.

Front Panel Controls: There are three lamps and an emergency stop button. Lamps may be filament bulb or LED cluster type. The three lamps are:

System Energized Lamps: These lamps light when the system is switched on.

Search Lamp: This lamp will light shortly after the operator presses search key on the console, during scanning. The function of this lamp is to alert the person performing the search of luggage that the operator of X-ray system has located. A buzzer is also connected to lamp circuit to provide audible warning.

X-Rays On Lamp: These lamps light when the computer has requested that X-rays to be switched on.

Emergency Stop Button: It is used by the external system to shut down X-ray machine.

Computer Rack: It contains a complete PC ATX computer, which runs the X-ray machine software package.

3. BLOCK DIAGRAM OF XBIS[5]:

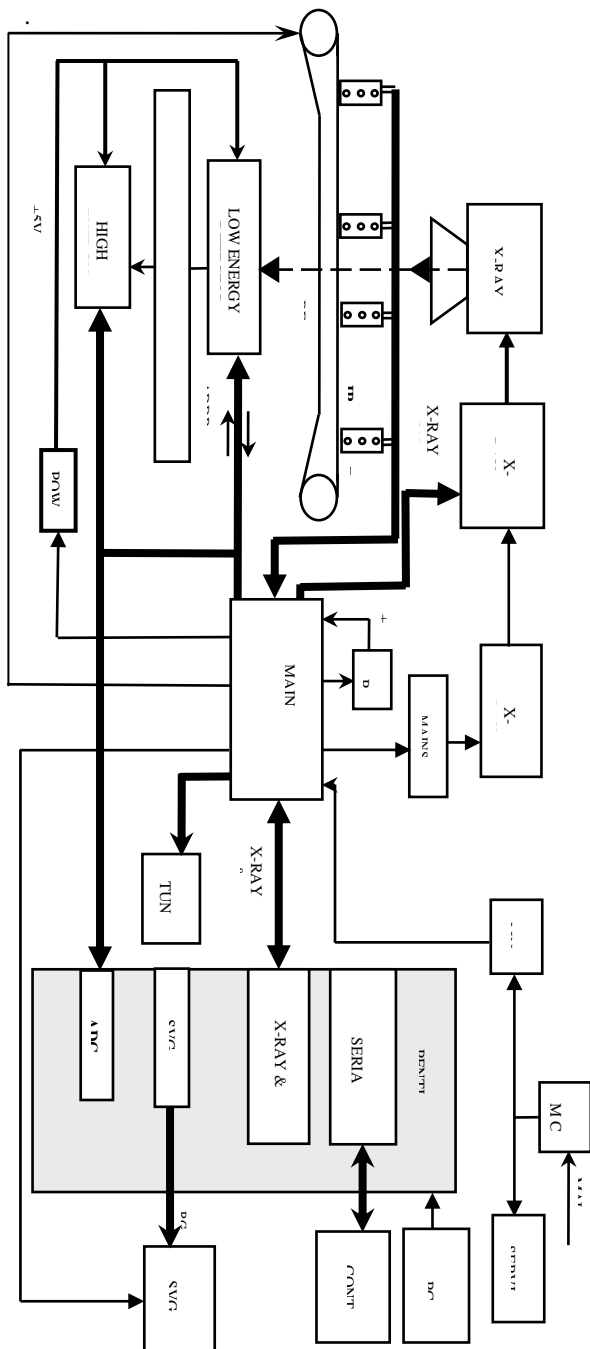


Fig 3: Series 500 System Block Diagram of XBIS

Working Principle:

XBIS is a compact system utilizing X-rays for the quick and efficient examination of handbags, parcels, suitcases, letters, books, etc. The unit is equipped with conveyor belt, which transports the luggage through the inspection tunnel. An X-ray generator supplies required radiation during screening. The emitted X-rays penetrate through the object under examination, which, while passing

through the unit, screen luggage piece slice by slice. The obtained picture information is then stored electronically and is processed to get a clear, informative image, which is finally reproduced on monitor screen.

Theory Of Operation:

All items to be inspected must be placed on the conveyor belt and the power is switched ON, then the items are transported to the inspection chamber. The items are placed flat in the center of the belt. They are so placed that even the smallest items can be inspected side by side if it is necessary. It is recommended that the leading edge of the conveyor break the sensor beam clearly. As the items reach the inspection chamber X-rays are automatically switched ON and image forming process begins and the inner objects of the luggage are displayed on the monitor.

In image forming process, the object is screened line by line as it moves on the conveyor belt. After the X-rays pass through the item to be inspected they strike a detector, which splits each line into more than 500 picture elements (pixels). This picture information is electronically processed, stored and finally reproduced on the monitor screen. The picture scrolls across the monitor as the item is being scanned. Image examination may be facilitated in any of 9 freely selectable image sections on the entire picture.

Imaging Sequence:

While system is idle, the scan engine is always running and collecting detector signals without X-rays. This signal is called **dark current**. Conveyor moves and brings baggage into the tunnel. Baggage blocks LS1 and software turns on X-rays. After a delay to ensure X-ray generator is fully up, software begins to collect data for full signal. This is called **light current**. After light current is collected software will calculate correcting factor for each channel. This whole process of dark current, light current and correcting factor is called **calibration**. When baggage reaches LS2, system begins to make an image. If calibration is incomplete, system will use previous calibration. At next time, system will continue light current collection.

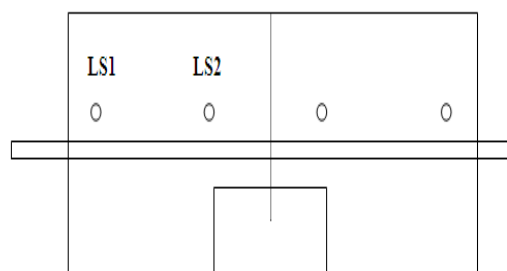


Fig 4: Imaging Sequence

After baggage passes LS2 a certain distance, software will stop generating image, but still keeps X-rays ON. If during the time X-rays are still ON, if new baggage reaches LS1, system will continue image processing without recalibration. This is done to prevent turning X-ray generator ON and OFF frequently to prolong its life. After some extra delay, if there is no other baggage entering tunnel, system turns off X-rays. To ensure X-rays are off, system begins dark current collection.

Collimation: X-ray system must be collimated for a good X ray image to be generated. The components to be adjusted

include:

1. The position of the generator focal point
2. The primary collimator sitting on the generator
3. The secondary collimator next to the tunnel on the generator side
4. The X-ray Sensor Amplifier PCB carrier rails.

Good collimation is achieved when all four components sit on the same plane.

Image Representation: Automatic exposure allows the operator to totally concentrate on the representation in interpretation of X-ray image. The picture quality and clarity helps the operator in making decision of whether the contents are safe or suspicious. The success of screening operation is dependent upon interpretation of image by the operator. The multi energy system distinguishes between materials according to their atomic numbers. The colors, which are displayed on monitor based on atomic numbers, are shown in the Table 1.

X-Ray Protection[2]: Considerable efforts have been made to ensure operator and equipment safety. XBIS is configured so that it provides reliable protection against hazardous radiation during operational mode. System employs extremely low X-ray dose and is designed in such a way that radiation is emitted only when object is transported. This equipment contains a set of lead-curtains on both entry and exit sides and an extensive lead shielding guarantees that radiation leakage and scatter practically zero. This way, X-rays will endanger neither passenger nor inspection personal even after numerous inspections. Several electronic safety circuits guarantee that radiation is immediately cut off in case inadmissible deviations from preset values are registered.

XBIS Standard Features:

1. Crystal Clear
2. Variable Edge Enhancement
3. Variable Gamma
4. Inverse Video
5. Pseudo Color
6. Variable Density Zoom
7. Organic/Inorganic Stripping
8. Variable Color Stripping
9. 2, 4, 6, and 8 times Zoom
10. Low & High Enhancement
11. View previous bag – two images

Table 1: Showing Different atomic numbers and their properties

ATOMIC NO'S (1-10)	ATOMIC NO'S (11-18)	ATOMIC NO'S (19-100)	ATOMIC NO'S ABOVE 100
Consists of mainly organic	Consists of mainly inorganic	Consists of steel and	Item that cannot be penetrated X-ray (lead)

materials containing elements of N ₂ , O ₂ & hydrocarbons.	aluminum, light metals and organic material over atomic number 10+.	materials and any substance over an atomic number of 18+	
<u>Dangerous items</u> Explosives, plastics, guns and narcotics.	<u>Dangerous items</u> Homemade bombs (chloride sugar)	<u>Dangerous items</u> Guns and knives	
<u>Non-dangerous items:</u> leather cloth paper, food wood, drugs	<u>Non-Dangerous items:</u> Light metal, combination of organic inorganic materials.	<u>Nondangerous items:</u> Pens, batteries, keys, radio, phone.	
<u>Colour:</u> Orange	<u>Colour:</u> Green	<u>Colour:</u> Blue	<u>Colour:</u> Black

4.XBIS MACHINE SPECIFICATION

1. GENERAL:

Resolution: 38 SWG, 42 SWG for solid copper
Penetration: 27 mm steel, 29mm typical
Material Separation: Low Z, Medium Z, High Z to 0.5 Z accuracy
Monitor: 17-inch SVGA color, non - flicker
Power: 230V a.c ±10% (50 Hz) 5Amps Max
Sensor: Folded array of diodes, 576 single array and 1152 dual array

2. X-RAY GENERATOR:

Cooling: Sealed Oil Bath with forced air
Anode Voltage: 160kV rated, operates 140kV
Tube Current: 0.7 mA typical
Beam Divergence: 60 deg
Orientation of X-rays: Vertically Upward
Dose per inspection: 0.15 mR (max)
Dose leakage: 0.1 mR per hr (max)

3. COMPUTER SPECIFICATION:

Processor: Intel Pentium IV
Memory: 512 MB RAM
Video Memory: 64MB
Hard Disk Drive: 40GB
CD-R/RW Drive: 52 X
 Access to keyboard port and parallel port is provided by means of a lockable access panel on the outside of the machine.

4. PHYSICAL SPECIFICATION:

Length: 2570mm (101.18 in.)
Height: 1345mm (52.95 in.)

Width: 835mm (32.87 in.)
Tunnel Size: 640mm (W) x 430mm (H).
 (25.2 x 16.93 in.)
Approx. Weight: (Net) 560 Kg (1232 lbs)
Gross: 760 Kg (1672 lbs)
Conveyor Speed: 0.22 m/sec (44ft/min)
Conveyor Load: 165Kg (365 lbs - evenly distributed)

5. ENVIRONMENTAL REQUIREMENTS:

Storage Temperature: -20°C to 50°C
Operating Temperature: 0°C to 40°C
Relative Humidity: 5 to 95% non-condensing

6. HEALTH AND SAFETY: [1] All XBIS systems are certified for use in public places by AERB (Atomic Energy Regulatory Board). Maximum leakage radiation less than 0.1mR/hr (1µ Sv/hr) in contact with outer panels. Film Safety: For ISO 1600/33 DIN, guaranteed up to 10 times exposure to radiation.

5. LINE SCANNING PRINCIPLE

There are two methods that XBIS implements in line scanning principle: Conventional method and Total Screening method.

- 1. Conventional Method:** In this method the item of luggage is routed past a linear detector line by means of conveyor belt. The detector line consists of single detectors rowed up in a line and positioned transverse to the direction of motion of conveyor belt. The detector line is exposed to a fine, fan shaped X-ray beam. The detectors consist of scintillators, which convert the X-ray radiation into visible light, and a semi-conductor photodiode, which converts light into electrical signal. The X-ray radiation is absorbed almost completely in the scintillator, thus providing good protection of the photodiode against the X-ray radiation. The output voltages of detector elements are measured in fast sequence, converted to digital signals and written into digital memory in columns. The video memory is read out in uninterrupted sequence line by line and after digital to analog conversion generates image on the monitor.

- 2. Total Screening Method:** By means of new arrangement of X-ray generator and detector lines it is made possible to solve the problem of corner cutting of objects, taking entire space of the inspection chamber. The radiation emitted by X-ray generator does not penetrate the objects centrally, but diagonally, while at the same time the detector line encloses the control chamber from the two sides. The geometric distortion caused by the angular line is electronically corrected.

Fig 6: X-Ray Sensor Amplifier PCB

The Main Parts of X-Ray Sensor Amplifier:

1. Scintillator diode, 2. Hybrid circuit,
3. Multiplexer 4. Buffer & Preamp,
6. Gain amplifier, 6. Comparator & Decoder

Principle:

The luggage is routed past detector lines by means of a

Scanning Principle: This scanning principle produces a luminous screen with low energy offered by a single detector in conjunction with directly coupled scintillate which results in a extremely low noise image in which gray differences can be detected, thus considerably improving both penetration as well as detection of thin wires. With X-ray generator, which generates a maximum dose of 0.1mR in the test object per sweep at an anode voltage of 140kV and anode current of 0.5mA, steel with a thickness of at least 10mm, is penetrated whereas copper wires with a maximum diameter of 0.16mm are still detected.

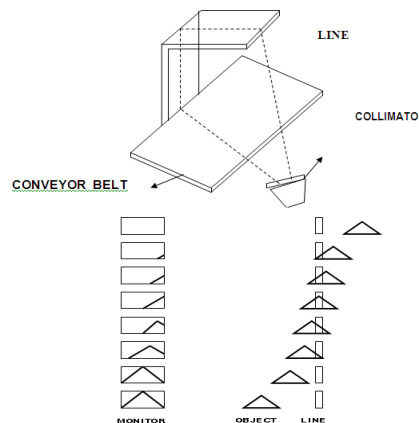


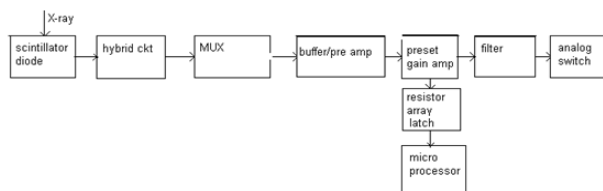
Fig 5: Object Alignment for Total Screening Line Scanning

5. X-RAY SENSOR AMPLIFIER PRINTED CIRCUIT BOARD

X-ray sensor amplifiers form the front end of the system. These are positioned transverse to the direction of the light. Diode array converts beam of X-rays into electrical signal which in turn is converted to digital data by A to D Converter and then received by the image processor board to produce the image. Two banks of X-ray sensor amplifiers, inner and outer boards are used in multi energy system. X-ray sensor amplifier PCBs are known as Diode Array PCBs.

A bank of diode arrays are used to convert the beam of X-rays into an electrical signal which is converted to digital data by the ADC, and is then interpreted by X-ray machine software to produce an image.

WARNING: Handle the diode array PCBs only by their edges. The PCB will malfunction if a finger mark or other contamination is present.



conveyor belt. The detector line consists of 1280 single detectors, which are rowed up a 2.5mm distance from center to center. The resulting detector line is positioned in line with collimator. The detector line is exposed to fan shaped X-ray beam. The detector consists of scintillator, which converts X-ray radiation to visible light, and semi-conductor photodiode, which converts light of scintillator into electrical signal. Output voltage of detector element is measured in a fast sequence, converted to digital signals and written into digital

video memory in columns. The video memory is read out in an uninterrupted sequence line by line and after digital to analog conversion generates image on the video monitor with SVGA format generated by detector element.

Addressing Signals in X-ray Sensor Amplifier:

Image processor controls the bank of X-ray sensor amplifier PCBs in a XBIS system. The processor sends out 12 address signals to select one pair of diodes in the bank, the board recognizes that it has been selected when the data on the address line (A6-A9) matches the board address set by the hexadecimal switch. IC-50 (74HC688) performs this function by comparing ‘P’ & ‘Q’ inputs. When the data matches, BDEN (board enable) goes low on both inner and outer boards. When BDEN goes low A11 is high, IC-51 is selected and decodes the address lines A4 & A5. This selects the one of the four multiplexers (DG406). This is done by enable signals EN1, EN2, EN3, EN4. The address line A0-A3 selects onediode from this channel.

Working:

After the X-rays scan through the luggage, they impinge on the cesium iodide crystal. The cesium iodide acts as a scintillator and converts these X-ray into light of particular wavelength (550nm). The photodiode, which has a good response to this wavelength, will convert the light into current in the order of a fraction of nano amperes (10E-9).The obtained current is fed into the hybrid circuit where the current is converted into voltage. As there are 64 diodes in an X-ray sensor amplifier PCB, these 64 output voltages obtained from current to voltage converter are fed into the 4 multiplexers. The outputs of multiplexers are connected parallel and are fed to the buffer, which avoids variations in the voltage and gives out smooth output. A capacitor which is placed across the input of the buffer output is spread into the gain amplifier. The gain amplifier is used to compensate the offset gains obtained from the address lines A0-A5. The output of gain amplifier is filtered by RC filter and routed through quad switch to flash type ADC. The capacitor used across ground and supply voltage is used to remove spikes in the supply after X-rays are converted into the voltage. The analog voltage is fed into an ADC for storing the data into the memory. The ADC used is fed into the processor where the digital data gets processed with the help of 21 bit digital signal processors. The memory capacity used in multi energy system is 1M*21 bit. The stored memory data (digital) is converted into analog data with the help of digital to analog converter for displaying data on monitor. The memory used in Multi energy system is according to SVGA standards i.e. 1000 X 800 pixels.

7. CONCLUSION, MERITS, DE-MERITS AND APPLICATIONS :

Conclusion:

For more than 100 years X-ray technology has been instrumental in exposing details hidden from the human eye. The ability to detect explosives, narcotics and weapons has become increasingly important to your security. X-ray machines are a perfect solution for the quick but thorough inspection of baggage. Hence, X-ray Baggage Inspection System is an ultimate innovation to meet the increased security at various vital places.

Advantages of the XBIS System:

1. Screening the contents of the luggage without opening the bag.
2. Faster way of luggage screening.
3. The screening is done in a much reduced amount of time as compared to that of manually.
4. The system is designed to provide both high through put and provide and detailed examination of carry on luggage and other articles by non-technical operating personal.
5. It is advantageous because it does not produce any radiation dosage threat to the operating personnel.

Disadvantages of the XBIS System:

1. A tamed pack of bag full of iron, heavy metal will look totally black from which the illegal materials are difficult to be detected.
2. There may be shock hazards,[4] which may prove fatal.

Applications:

X-Ray Baggage Inspection system scans different baggage which can be scanned with different system series as shown in table 2.

Table 2:Different versions of XBIS

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Application	System Type Number	Specifications Tunnel size W x H (in mm)	Generator orientation
Hand Baggage	ECR 520 ECR 522B ECR 619	640 x 430 750 x 550 550 x 375	Bottom
Check-in Baggage	ECR 530 ECR 526B ECR 526A ECR 527	1200 x 800 950 x 850 900 x 750 1000 x 1000	Side Bottom Top Bottom
Cargo	ECR 532H	1500 x 1650	Side
Parcel viewer	ECR 519/419	500 x 300	Bottom

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