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(54) **HIGH-SPEED SECURITY INSPECTION SYSTEM**

SCHNELLES SICHERHEITSÜBERPRÜFUNGSSYSTEM

SYSTÈME D'INSPECTION DE SÉCURITÉ À GRANDE VITESSE

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Description

FIELD

[0001] The invention relates generally to security systems for screening threats and contraband contained on vehicles, for example, for screening cargo carried on a high speed rail system, such as a rail cargo car.

BACKGROUND

[0002] The physical shipment of materials, including the shipment of mail, merchandise, raw materials, and other goods, is an integral part of any economy. Typically, the materials are shipped in a type of shipping containment or cargo box. Such containments or boxes include semi-trailers, large trucks, and rail cars as well as intermodal containers that can be carried on container ships or cargo planes. However, such shipping or cargo containers can also be used for illegal transportation of contraband. Detection of these threats requires a safe and accurate inspection system, yet one that is also highly efficient so as to not impose an excessive delay or processing burden on very high volumes of goods.

[0003] In particular, there exists a requirement for automated scanning of cargo carried by train for the purpose of security inspection. This cargo is typically in containerized form, whereby the container has a standard size and shape. Trains carrying cargo containers typically travel at a high speed (in the range 20 km/h to 150 km/h); therefore, the security inspection process should be capable of being conducted at these high speeds without interfering with the flow of trade. Further, the system must not expose any worker who may be present on the cargo train to radiation, such as a driver or guard, while radiation exposure to an individual who may be hidden within the cargo should be reduced to a reasonably low level.

[0004] Known scanning processes for inspection of containerized cargo include X-ray scanning, chemical analysis of vapour emitting from the cargo, listening to sound from the cargo to detect living objects and eventually interventional manual search of the cargo by one or more security officials.

[0005] Most common in almost all regions of the world is the use of X-ray scanning for scanning containerized cargo. Here, a variety of systems have been developed including mobile scanners (which drive past the object under investigation during scanning), trailer-based scanners (where the vehicle under inspection drives through the inspection zone), gantry-based scanners (which drive along rails past the object under inspection during a scan) and portal mode scanners (where a vehicle drives through the scanner and either the entire vehicle or just the cargo is scanned).

[0006] Most X-ray scanning systems use either a linear accelerator or an X-ray tube to produce the necessary penetrating radiation within a tightly collimated fan-beam of X-rays. Linear accelerator systems use energies typically in the range 1MV to 9MV while X-ray tube based systems use energies in the range 100 kVp to 450 kVp. Alternate radiation sources include gamma-ray emitting materials such as Co-60 or Cs-137 or X-ray sources such as betatrons. Occasionally, neutron sources are used for scanning cargo, including isotopic sources such as Am-Be or Cf-252 or electronic source such as D-D or D-T pulsed neutron generators.

[0007] In each case, the scanning speed of the system is constrained by factors such as the pulse rate achievable from the Linear Accelerator or the allowable dose rate from the X-ray tube to provide sufficient penetration of the cargo while simultaneously providing safe scanning of occupied cargo.

[0008] Systems known to those of skill in the art operate at scanning speeds of less than 15 km/h to preserve an acceptable image quality. This speed is determined by the pulse rate from the fan-beam X-ray source and the relatively narrow width of the X-ray sensor array.

[0009] There is therefore a need for a scanning system which is not constrained in providing higher scanning speeds that are required for screening cargo on rail cars. Additionally, such a scanning system is required to maintain excellent image quality regardless of scanning speed.

[0010] US 2011/0038453 discloses a self-contained mobile inspection system with dual energy scanning capability.

SUMMARY

[0011] The present invention provides an X-ray system for scanning moving cargo with a speed in the range of 20 km/h to 150 km/h according to claim 1.

[0012] Optionally, the moving cargo is propelled along the trajectory by a train.

[0013] Optionally, the moving cargo is propelled along the trajectory by a truck.

[0014] Optionally, the X-ray system further comprises a collimator positioned proximate to said detector array to reject scattered radiation from the detector array. Optionally, the collimator comprises a plurality of collimator sheets configured into a plurality of rows and columns to form a grid.

[0015] Optionally, the control system is located remote from said scanning system.

[0016] The aforementioned and other embodiments of the present invention shall be described in greater depth in the drawings and detailed description provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other features and advantages of the present invention will be appreciated, as they become better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 provides an overview of the system geometry, according to one embodiment of the present invention;

FIG. 2 illustrates a top view of an inspection zone, as shown in FIG. 1;

FIG. 2a is a plot graphing pulse rate versus speed of the cargo under inspection;

FIG. 3a illustrates an exemplary arrangement for a single track installation of the scanning system described in the present specification;

FIG. 3b illustrates an exemplary arrangement for a twin track system installation of the scanning system described in the present specification;

FIG. 4a illustrates a collimator assembly used to reject scattered radiation from the detector array;

FIG. 4b illustrates another collimator assembly used to reject scattered radiation from the detector array;

FIG. 4c illustrates another collimator assembly used to reject scattered radiation from the detector array;

FIG. 4d illustrates another collimator assembly used to reject scattered radiation from the detector array;

FIG. 5 is a graph showing material discrimination between high atomic number (High-Z) and low atomic number (Low-Z) materials;

FIG. 5a illustrates dual energy imaging, according to one embodiment of the present invention;

FIG. 6 provides a representative layout of a train scanner system according to one embodiment of the present invention;

FIG. 7 illustrates a block diagram of a control system, forming part of one embodiment of the system described in the present specification;

FIG. 8 is a diagram illustrating an exemplary scanning process; and

FIG. 9 is a diagram illustrating an exemplary remote networked installation of the system described in the present specification.

DETAILED DESCRIPTION

[0018] Some embodiments of the present invention include systems for detecting contraband and threats in cargo carried by a train travelling on a railway, using a scanning system design that is able to provide higher scanning speeds, in the range 20 km/h to 150 km/h. The scanning system described in the present specification also produces excellent image quality in spite of the high scanning speed.

[0019] In one embodiment described in the present specification, the system advantageously uses a two-dimensional X-ray sensor array combined with a cone-beam X-ray geometry, instead of projecting a tightly collimated X-ray fan-beam onto a narrow column of sensors as has been available in prior art. The scanning system described in the present specification further allows for maximum threat detection with minimum false alarms, and thus increased throughput.

[0020] In one embodiment described in the present specification, the scanning system advantageously recognizes that the precise timing between X-ray exposure and the speed of the passing object is critical and dependent upon the width of the two-dimensional array of X-ray sensors.

[0021] The present specification is directed towards multiple embodiments of the invention. The following disclosure is provided in order to enable a person having ordinary skill in the art to practice the invention. Language used in this specification should not be interpreted as a general disavowal of any one specific embodiment or used to limit the claims beyond the meaning of the terms used therein. The general principles defined herein may be applied to other embodiments and applications without departing from the scope of the invention. Also, the terminology and phraseology used is for the purpose of describing exemplary embodiments and should not be considered limiting. For purpose of clarity, details relating to technical material that is known in the technical fields related to the invention have not been described in detail so as not to unnecessarily obscure the present invention.

[0022] An overview of the system geometry of some embodiments is provided in Figure 1. Referring to Figure 1, a linear accelerator X-ray source 101 is shown irradiating a cone-beam of X-rays 102 onto a two-dimensional X-ray detector array 103. The detector array 103 and the X-ray source 101 are located on the opposite sides of an inspection zone, which in one embodiment is the area around railway track 104 through which a train carrying cargo containers travels. Although embodiments of the invention are described in the present specification in the context of automated scanning of cargo carried by rail, one skilled in the art would appreciate that the system of shown in Figure 1 may be applied to scanning cargo in any vehicle, and implemented in any configuration such as mobile, trailer, gantry and portal configurations, as required by the application.

[0023] In one embodiment, the X-ray inspection system works with the cargo moving in a substantially linear path as it passes through the scanning zone. To allow accurate scanning of the rail cargo passing on the rail track between the X-ray source and the detector, this embodiment of the present invention ensures precise timing between the X-ray exposure and the speed of the passing object. This critical timing is, in turn, dependent on the width of the two-dimensional array of X-ray sensors. Figure 2 shows a view of the inspection zone 202 from above, looking down to the plane of the track 201. As can be seen from the figure, it is necessary that the distance that the cargo travels between X-ray pulses 203 is substantially, and in one embodiment not covered by the claimed invention exactly matched by the width of the detector 204, for a single energy system. In case of a dual energy system, the distance is equal to exactly half the width of the detector. The use of dual-energy imaging is recommended for the best in image quality since all regions of the object under inspection are fully analysed in this case, and thus, according to the invention, the system of the present invention employs a dual energy X-ray source.

[0024] Therefore, the X-ray pulse is timed to pulse based upon the speed of the passing cargo and based upon the known detector size, such that the distance the cargo travels between pulses is substantially equal to half the detector width. It should be appreciated that the controller systems used to operate the X-ray source and the processing system used to process detected data may be pre-programmed with half the known width of the detector.

[0025] In a further aspect of the invention, the control system which drives the X-ray source modulates the pulse rate of the X-ray source in direct proportion to the speed of the passing cargo. This is shown in Figure 2a, which plots pulse rate 210 versus speed of the cargo 211. The gradient of this graph is a simple function of the width of the detector array, that is, wider the detector array, smaller the gradient of the graph.

[0026] As an example, consider that a train is moving through the system at 100 km/h. This is equivalent to a speed of 27.8 m/s. For an X-ray source with maximum pulse rate of 300 Hz, the width of the detector array scaled to the center of the cargo should be 27.8 m/s divided by 300, which is equal to 0.093 m, in the case of single energy imaging or 0.185 m in the case of dual-energy imaging. The same simple calculation can be used to calculate pulse rate or detector width in any other situation. As an example, for a dual energy system with detector width of 0.185m scaled to the centre of cargo, then at a scanning speed of 50 km/h, the linear accelerator (Linac) pulse rate should be 150 Hz.

[0027] In one embodiment, the spatial resolution of the system is specified in order to determine the number of detector elements which are required within the two-dimensional array of detectors, after determining the required width of the detector array. For example, if a 4 mm grid resolution is required in the generated image at 100 km/h with a maximum pulse rate of 300 Hz in a dual-energy imaging system, then the individual detector element width scaled to the center of cargo should be no more than 4mm, so requiring at least (185/4) = 47 detectors over the width of the detector array.

[0028] To minimize the cost of the X-ray detector array, it is reasonable to reduce the magnification of the system to ensure that the width of the X-ray detector array is as close as possible to its scaled width at the center of cargo. Therefore, as shown in Figure 3a, in one embodiment the X-ray source 301 is ideally located far from the cargo 302, while the detector array 303 is placed close to the cargo. This is because the more the individual X-ray beams within the cone-beam 304 are parallel, the better is the final image quality on account of reduced parallax between adjacent projections in the X-ray image. However, the further the X-ray source is from the cargo, the more the reduction in signal intensity due to inverse square law. This leads to lower penetration performance of the X-ray image for given source intensity. Thus, there is a trade-off between image quality, penetration performance and ultimately radiation protection issues. This trade-off is typically analysed by one skilled in the art given the particular constraints of the required installation site and image performance requirements.

[0029] As shown in Figure 3a, a single straight detector array 303 is employed in a single track rail installation used for scanning a single unit of cargo 302 at a time. Figure 3b shows a twin-track system for simultaneous scanning of two adjacent units of cargo, 312 and 322. In this embodiment, the twin-track system is more advantageously serviced by two sections of detector array - a vertical section 323 in combination with an inclined array section 313. In an alternative embodiment, a single curved array section may be used instead of a combination of a vertical and an inclined array sections. Accordingly, the X-ray source 392 is directed toward, and aligned with, a first detector array 323, positioned vertically (or perpendicularly) relative to a ground surface, and a second detector array 313, positioned above the first detector array and at an acute angle relative to the ground surface in the direction of the X-ray source 392.

[0030] One of ordinary skill in the art will recognize that X-rays interact with matter through various mechanisms in the energy range of interest, which is 50 keV to 9 MeV. The most important mechanisms in this context are Compton scattering, photoelectric absorption and pair production. Both photoelectric absorption and pair production effects result in loss of an X-ray from the primary beam with re-emission of lower energy radiation (characteristic X-rays and 511 keV gamma-rays respectively). However, Compton scattering results in both energy and direction change of the incident X-ray. Thus, an X-ray which was previously travelling along one path can be diverted to move along a new path. This scattered X-ray can interact with the wide detector array which is the subject of this invention, resulting in a reduction in radiographic contrast. This has a negative impact on overall system performance.

[0031] To counter this negative impact, in a further aspect of the present invention, a collimator is provided which is used to reject scattered radiation from the detector array. This improves image contrast and ultimately also penetration performance of the system. Figure 4a shows two sheets, 401 and 402, of a suitably attenuating material which are cut or otherwise machined into comb like structures. Suitable materials for such sheets include pure tungsten, alloys of tungsten, and alloys of lead or other high-Z materials which can be easily machined, such as Molybdenum or steel. The thickness of the attenuating sheets depends on factors such as the detector pitch, the spacing between individual detector elements within the detector array and the spectral distribution of X-ray energies produced by the X-ray source. In one embodiment, after considering all the aforementioned factors, the thickness of the attenuating sheets 401, 402 are chosen to be in the range 0.3 mm to 1.5 mm.

[0032] Figures 4b, 4c, and 4d show assembly steps for manufacturing an exemplary collimator for use in embodiments of the present invention. Figure 4b shows how the two sheets shown in Figure 4a interlock to form a cross-like structure 403. Figure 4c shows how multiple cross-sheets 404 have been interlocked using a single sheet 405. Figure 4d shows a full two-dimensional interlocked array of collimator sheets 406 employed to cover the entire detector module. When fully constructed, then, the array of collimator sheets 406 comprise a plurality of rows and columns formed from individual collimators 405, 404, wherein the plurality of rows and columns create a plurality of hollow space, or cells.

[0033] In one optional embodiment, spacers are provided at the base and top of each column in the array of collimator sheets 406, to ensure that the collimator aperture remains open, should the material itself become warped following machining of the interlocking slots, thus lending structural strength to the array of collimator sheets. These spacers are, in one embodiment, advantageously fabricated from a low attenuation material such as plastic or aluminium to minimise their impact in the X-ray image.

[0034] The performance of the collimator is affected by the ratio of length to width of the individual collimator openings. The higher the ratio of length to width, the better the scatter rejection of the collimator; however, such an embodiment is more expensive to manufacture. A length to width ratio ranging from 5 to 50 is ideal, and even more specifically, a length to width ratio of about 20 is likely to be found to have the best engineering optimization.

[0035] In order to provide the most diagnostic information, the security scanner of the present invention is provided with materials discrimination capability. Here, coloring is applied to each individual pixel in the image. The color is dependent on the average atomic number along the path that the X-rays have followed from source to detector. This means making a measurement of each volume integral through the object at two different energies, and comparing the transmission of the X-ray beam at both high and low effective energies. The result is a plot substantially as shown in Figure 5. H refers to the high energy signal and L refers to the low energy signal. The difference (H-L) 501 is plotted on the vertical axis and the sum (H+L) 502, or the average value of H, L is plotted on the horizontal axis. The resulting graph 503 shows High-Z and Low-Z materials distinctly. In one embodiment, the graph 503 is turned into a look-up-table for colouring individual pixels to distinguish materials in the image. Further smoothing may be applied to the image to reduce the impact of photon noise as required.

[0036] In a further aspect of the present specification, the cone-beam detector array shown in Figures 1 and 2 is arranged such that each pixel in the detector array is irradiated twice, once with a high energy beam and once with a low energy beam for every point in the cargo. Figure 5a illustrates how one embodiment of the current invention provides dual energy imaging capability. Referring to Figure 5a, the full detector array 510 is first illuminated by a high energy X-ray beam 511. Once the cargo has travelled a distance equal to half the width of the detector array, the entire detector array is again illuminated by a low energy X-ray beam 512. Therefore, there is a region of overlap 513 between the two pulses at different energy, which forms the basis of the signal for materials characterisation. Data from the array needs to be re-arranged following each X-ray pulse so that half the data from the array from the given pulse goes to form the materials separation image with data from the other half of the array in the subsequent pulse. The other half of the data from the given pulse is used to match data from the previous pulse. It should be appreciated that a controller, programmed with the detector width and receiving a signal from a speed sensor regarding the passing speed of cargo, is used to control the timing, and selection, of a high energy pulse and a low energy pulse.

[0037] In a further aspect of this invention, it is necessary to provide a time accurate control system to ensure that each X-ray pulse occurs at exactly the right time, this time being dependent on the current speed of the cargo and on whether or not the cargo is present in the X-ray beam region. As an example, consider a train moving at 100 km/h. This equates to a distance of 93 mm per pulse at a pulse rate of 300 Hz. The control system should therefore be capable of ensuring pulse stability of better than half of the spatial resolution of the system, or around 2% of this distance (= (1/300) * 0.02 = 0.067 ms) with beam on-off switching times calculated to better than half the jitter time between X-ray pulses (i.e. 1.5ms at 300 Hz pulse rate).

[0038] Figure 6 provides a representative layout of a train scanner system for operation at these high scanning speeds. An arriving train triggers an axle counter 601 which is installed on rail track 602. The axle counter is a reliable device which can provide time as well as speed and direction information. One or more infra-red barriers 603 are placed above the track. When the cargo intercepts these light beams, a precise time is derived for the start of cargo relative to the last time at which an axle crossed the axle counter. The light beam state change triggers an optical recognition system 604 to capture images from one or more sides of the cargo. The optical recognition 604 system also records container numbers from the passing cargo.

[0039] As the train passes along the rails to the scanning zone 606, the axles will start to trigger the second axle counter 605 adjacent to the scanning zone. The control system then calculates the time at which the leading and trailing edges of the cargo will pass though the X-ray beam, typically to sub-millisecond accuracy, referred to the most recent axle crossing. The control system then activates an X-ray enable signal to force turn on and off of the X-ray beam from the source 607 at the appropriate times, which is suitable detected by the detector array 608 on the opposite side of the track 602.

[0040] Figure 7 illustrates a block diagram of a control system, according to one embodiment of the present invention. The control system advantageously comprises a microprocessor 701 with electronics support to record the event times from the various system sensors, including IR sensors 702, optical recognition system 703 and axle counters 1 and 2, 704 and 705, respectively. The microprocessor 701 uses these inputs to calculate the X-ray on and off times 706. In parallel, a standard safety system built around a process logic controller (PLC) 707 monitors the health of E-Stop circuits 708, associated X-ray interlock circuits 709 and operator driven system enable signals to provide one or more signals 710. The signal 710 from the PLC 707 is gated by an AND gate 711 to provide the X-ray on-off gate to the X-ray source 712. The circuit of Figure 7 provides low latency, low jitter timing for the X-ray on/off signals to meet the demands of high speed inspection.

[0041] In a further aspect of the present specification, the results from the optical recognition system are used to determine whether or not an X-ray image should be acquired for each component of the train. Here, the IR sensors are used to determine the start and end time for each object on the train including locomotives, carriages and other non-containerised cargo. The IR sensors trigger acquisition of optical images of the cargo which are analysed by automatic container code recognition software. If no valid container code is recognised, no X-ray of that cargo shall be conducted. If, however, a valid container code is recognised, then the cargo shall be scanned. This process is summarised with the help of an example in Figure 8. Here four potential cargos 801 are recognised by the IR beams. Each possible cargo is identified with a sequential number as it passes through the entrance line to the scanner. At some point later, the optical recognition system returns with an inspection result 802, correlated with the IR cargo number. Thus, for each cargo container, the optical recognition may return a simple Yes or No, or may also include a confidence level on the inspection result. In one embodiment, the confidence level represents a code which has been recognized with a valid checksum. Thus, for example, a confidence of 90% or more implies that the required code has been correctly recognized along with a valid checksum. Less than this level of confidence would imply that a valid code pattern has been recognized but with an incorrect checksum, that is one or more characters have been read incorrectly.

[0042] Where a positive optical recognition inspection result is received for a given cargo, and that inspection result is accompanied a satisfactory confidence level, then that cargo will then be X-rayed. Figure 8 shows an example where three out of a possible four cargos are inspected since one optical recognition result 803 returned a 'No'. There is no X-ray scan for the 'No' cargo 803, as visible from the scan line 805. To maximize optical recognition reliability, it is recognised that more than one optical recognition system may be used to analyze container numbers from a single container. Thus, in one embodiment, the system employs two optical recognition systems viewing either side of the container, with a third one monitoring the number on the roof of the cargo. More the number of optical recognition systems used, more reliable the system becomes. One of ordinary skill in the art would appreciate that additional safety protocols can further be introduced. In one embodiment for example, all optical recognition systems are required to return a valid result. This reduces operational scanning yield, but will also correspondingly reduce the probability of falsely irradiating non-containerised cargo.

[0043] It shall be recognized by one skilled in the art that alternative control systems can be designed using different sensor technologies, such as scanning laser sensors, inductive sensors, 3D visible light cameras and so on, as well as alternate configurations of the sensors already identified. It should also be appreciated that control systems can be designed for single track single direction scanning, single track bi-directional scanning and even multi-track, bi-directional scanning. Rather than using fully automated control systems, semi-automatic control systems may also be used in which an operator loads a train configuration prior to the scan. In some circumstances, a manual control system may be advantageous whereby an operator selects whether a cargo should be scanned as it passes through the system. The final choice of control system is always dependent on local requirements. In every case, the key inventions described herein remain valid.

[0044] In a further aspect of this invention, it is recognized that it may be advantageous for such an automated system to work in a situation which is remote from the system operators. Figure 9 shows an example of a networked installation where the source 901, sensor 902, PLC 903, control system 904 and data acquisition system are sited at the scanning location while the operator workstations 911, the system administrator 912 and main database 913 are located at a more convenient, but remote, site. They are joined by a network 920 using switches 915. The network 920, in one embodiment, is advantageously an optical fibre based system in order to deal with relatively high data rates and the long distances which may well be involved.

[0045] The above examples are merely illustrative of the many applications of the system of present invention. Although only a few embodiments of the present invention have been described herein, it should be understood that the present invention might be embodied in many other specific forms without departing from the scope of the invention. Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention may be modified within the scope of the appended claims.

Claims

1. An X-ray system for scanning moving cargo with a speed in the range of 20 km/h to 150 km/h, the system comprising:

an X-ray source (101) configured for generating a cone-beam of X-rays to irradiate the moving cargo, wherein the moving cargo travels along a linear trajectory perpendicular to the plane of the cone-beam of X-rays and wherein the X-ray source (101) is a dual energy source configured to generate a high energy beam (511) and a low energy beam (512)of X-rays;
at least one two-dimensional detector array (103) to receive the cone-beam of X-rays transmitted through the moving cargo, wherein said X-ray source (101) and said at least one detector array (103) are placed on opposite sides of the moving cargo;
a sensor configured to measure a speed of the moving cargo; and
a control system arranged to

receive data indicative of said speed from the sensor,
pulse the X-ray source (101) and alternate between the high energy X-ray beam (511) and the low energy X-ray beam (512) on each subsequent pulse, and
modulate a pulse rate of the cone-beam of X-rays such that the distance travelled by the moving cargo between each X-ray pulse is substantially equal to half the width of the detector array (103) and wherein data from half the detector array (103) from a given pulse is used to form a materials separation image together with data from the other half of the detector array (103) from a subsequent pulse.

2. The system of claim 1 further comprising a collimator (403) positioned proximate to said detector array to reject scattered radiation from the detector array.

3. The system of claim 2 wherein said collimator comprises a plurality of collimator sheets (401) (402) configured into a plurality of rows and columns to form a grid.

4. The system of any one of claims 1 to 3 further comprising a system (604) for acquiring optical images of the moving cargo.

5. The system of claim 4 wherein the control system is configured to receive optical data from said system (604) for acquiring optical image and, based on the optical data, configured to determine if said moving cargo should be scanned with said X-ray beam signals.

6. The system of any one of claims 1 to 5 further comprising a sensor system configured to determine a speed of the moving cargo.

7. The system of any preceding claim wherein said control system is located remote to said scanning system.

Patentansprüche

1. Röntgensystem zum Scannen einer Ladung, die sich mit einer Geschwindigkeit in dem Bereich von 20 km/h bis 150 km/h bewegt, wobei das System umfasst:

eine Röntgenquelle (101), die konfiguriert ist zum Erzeugen eines Kegelstrahls aus Röntgenstrahlen, um die sich bewegende Ladung zu bestrahlen, wobei sich die sich bewegende Ladung entlang einer linearen Bahn senkrecht zur Ebene des Kegelstrahls aus Röntgenstrahlen fortbewegt, und wobei die Röntgenquelle (101) eine duale Energiequelle ist, die konfiguriert ist zum Erzeugen eines Hochenergiestrahls (511) und eines Niedrigenergiestrahls (512) von Röntgenstrahlen;
mindestens eine zweidimensionale Detektoranordnung (103), um den Kegelstrahl aus Röntgenstrahlen zu empfangen, der durch die sich bewegende Ladung übertragen wird, wobei die Röntgenquelle (101) und die mindestens eine Detektoranordnung (103) auf entgegengesetzten Seiten der sich bewegenden Ladung angebracht werden;
einen Sensor der konfiguriert ist zum Messen einer Geschwindigkeit der sich bewegenden Ladung; und
eine Steuersystem das geeignet ist zum:

Empfangen von Daten, welche die von dem Sensor Geschwindigkeit anzeigen,
Pulsen der Röntgenquelle (101) und Alternieren bei jedem nachfolgenden Puls zwischen dem Hochenergieröntgenstrahl (511) und dem Niedrigenergieröntgenstrahl (512), und
Modulieren einer Pulsrate des Kegelstrahls aus Röntgenstrahlen, sodass die Entfernung, die von der sich bewegenden Ladung zwischen jedem Röntgenpuls zurückgelegt wird, im Wesentlichen gleich der Hälfte der Breite der Detektoranordnung (103) ist, und wobei die Daten von einer Hälfte der Detektoranordnung (103) von einem gegebenen Puls verwendet wird, um zusammen mit den Daten von der anderen Hälfte der Detektoranordnung (103) von einem nachfol-

genden Puls ein Materialtrennungsbild zu bilden.

2. System nach Anspruch 1, das außerdem einen Kollimator (403) umfasst, der in der Nähe der Detektoranordnung angebracht ist, um eine von der Detektoranordnung gestreute Strahlung zurückzuweisen.

3. System nach Anspruch 2, wobei der Kollimator eine Vielzahl von Kollimatorlamellen (401) (402) umfasst, die in einer Vielzahl von Reihen und Spalten konfiguriert sind, um ein Gitter zu bilden.

4. System nach einem der Ansprüche 1 bis 3, das außerdem ein System (604) zum Erfassen von optischen Bildern der sich bewegenden Ladung umfasst.

5. System nach Anspruch 4, wobei das Steuersystem konfiguriert ist zum Empfangen von optischen Daten von dem System (604) zum Erfassen von optischen Bildern und das aufgrund der optischen Daten konfiguriert ist zum Ermitteln, ob die sich bewegende Ladung mit den Röntgenstrahlsignalen gescannt werden soll.

6. System nach einem der Ansprüche 1 bis 5, das außerdem ein Sensorsystem umfasst, das konfiguriert ist zum Ermitteln einer Geschwindigkeit der sich bewegenden Ladung.

7. System nach einem der vorhergehenden Ansprüche, wobei das Steuersystem fern$_{17}$ von dem Scansystem angebracht ist.

Revendications

1. Système de rayons X destiné à inspecter une cargaison mobile avec une vitesse dans la gamme de 20 km/h à 150 km/h, le système comprenant :

   une source de rayons X (101) configurée pour générer un faisceau conique de rayons X pour irradier la cargaison mobile, la cargaison mobile se déplaçant le long d'une trajectoire linéaire perpendiculaire au plan du faisceau conique de rayons X et la source de rayons X (101) étant une source à double énergie configurée pour générer un faisceau de forte énergie (511) et un faisceau de faible énergie (512) de rayons X ;
   au moins un réseau de détecteurs bidimensionnel (103) pour recevoir le faisceau conique de rayons X transmis à travers la cargaison mobile, ladite source de rayons X (101) et ledit au moins un réseau de détecteurs (103) étant placés sur des côtés opposés de la cargaison mobile ;
   un capteur configuré pour mesurer une vitesse de la cargaison mobile ; et
   un système de commande agencé pour

      recevoir des données représentatives de ladite vitesse depuis le capteur,
      appliquer des impulsions à la source de rayons X (101) et alterner entre le faisceau de rayons X de forte énergie (511) et le faisceau de rayons X de faible énergie (512) sur chaque impulsion consécutive, et
      moduler une fréquence d'impulsions du faisceau conique de rayons X de telle sorte que la distance parcourue par la cargaison mobile entre chaque impulsion de rayons X soit sensiblement égale à la moitié de la largeur du réseau de détecteurs (103), et dans lequel les données issues d'une moitié du réseau de détecteurs (103) provenant d'une impulsion donnée sont utilisées pour former une image de séparation de matériaux avec les données issues de l'autre moitié du réseau de détecteurs (103) provenant d'une impulsion suivante.

2. Système de la revendication 1 comprenant en outre un collimateur (403) positionné à proximité dudit réseau de détecteurs pour rejeter le rayonnement diffusé loin du réseau de détecteurs.

3. Système de la revendication 2 dans lequel ledit collimateur comprend une pluralité de feuilles de collimation (401) (402) configurées dans une pluralité de rangées et de colonnes pour former une grille.

4. Système de l'une quelconque des revendications 1 à 3 comprenant en outre un système (604) pour acquérir des images optiques de la cargaison mobile.

5. Système de la revendication 4 dans lequel le système de commande est configuré pour recevoir des données optiques depuis ledit système (604) pour acquérir une image optique et, sur la base des données optiques, configuré pour déterminer si ladite cargaison mobile doit être inspectée avec lesdits signaux de faisceau de rayons X.

6. Système de l'une quelconque des revendications 1 à 5 comprenant en outre un système de capteurs configuré pour déterminer une vitesse de la cargaison mobile.

7. Système d'une quelconque revendication précédente dans lequel ledit système de commande est situé à distance dudit système d'inspection.

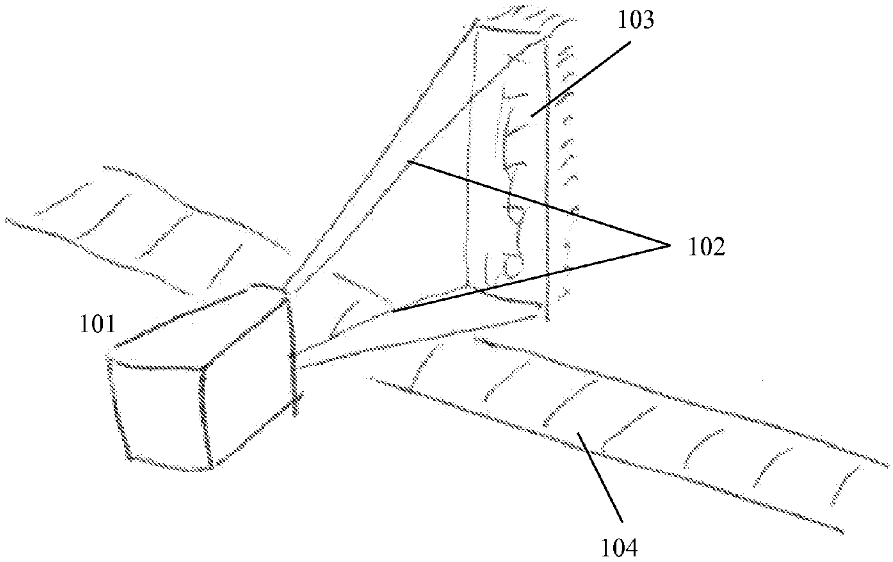


FIG. 1

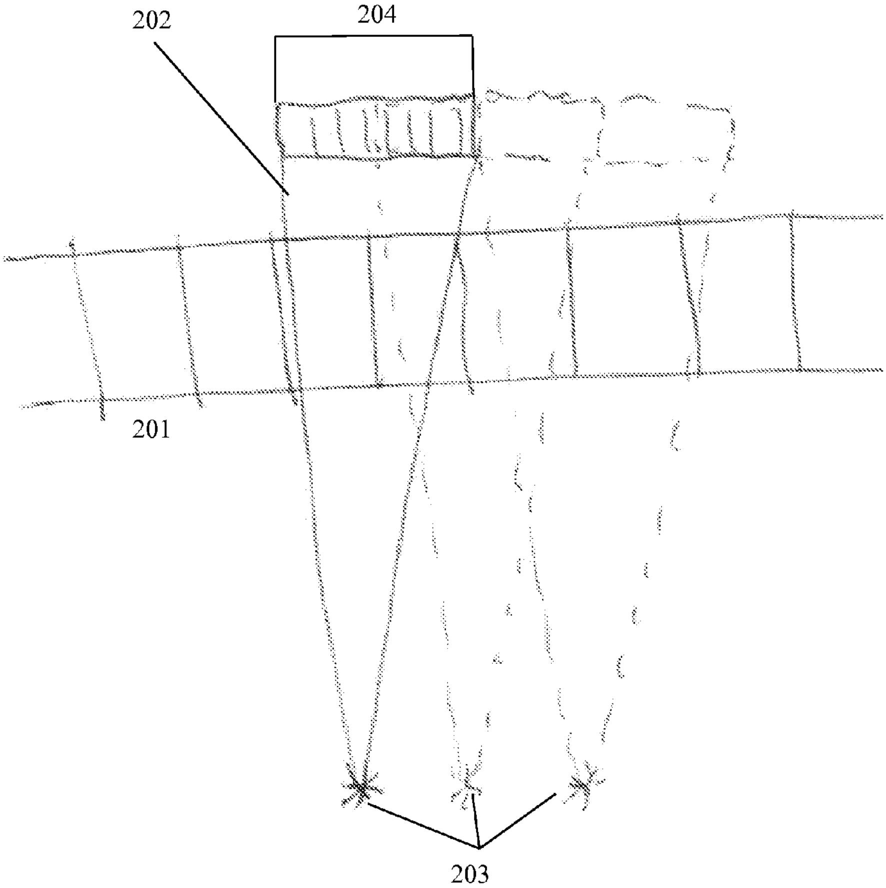


FIG. 2

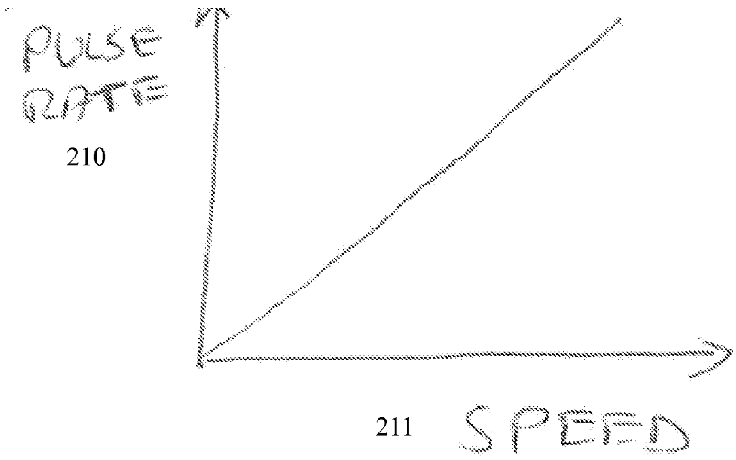


FIG. 2a

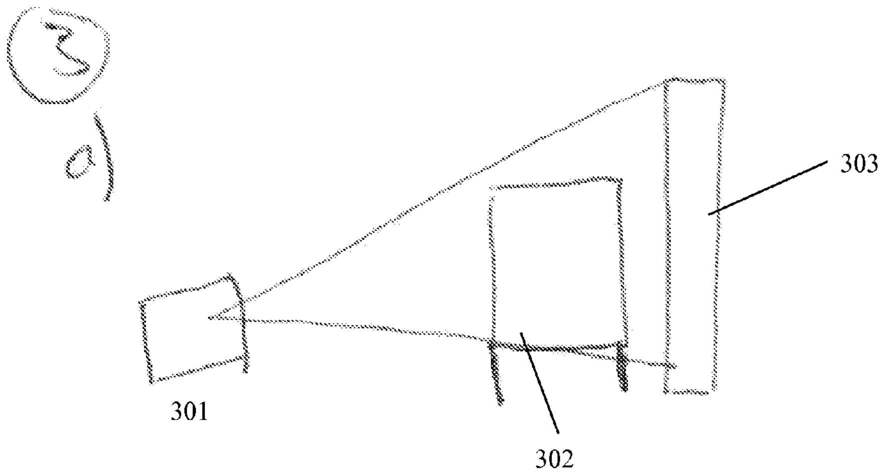


FIG. 3a

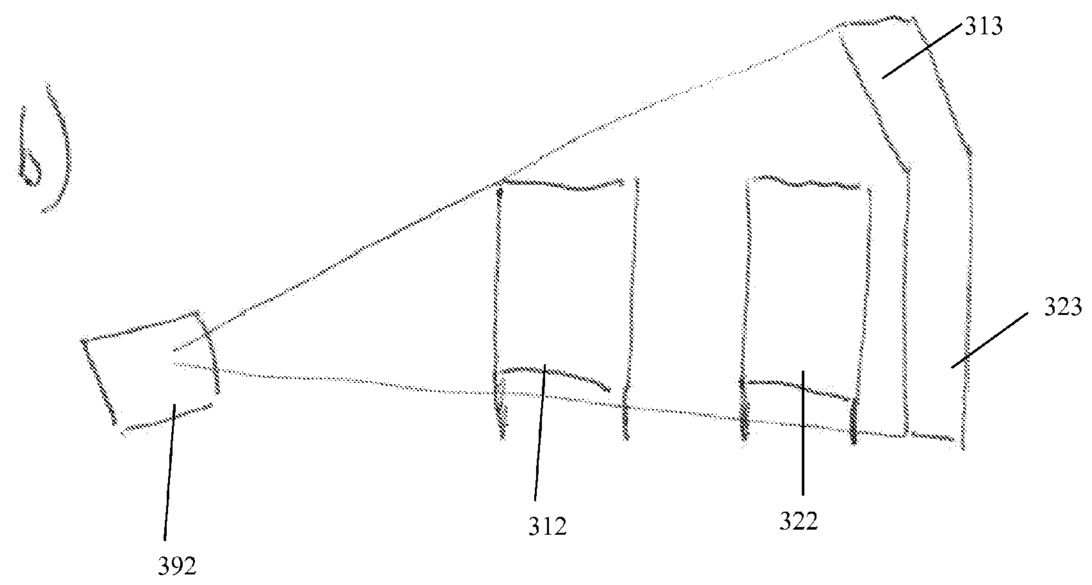


FIG. 3b

FIG. 4a

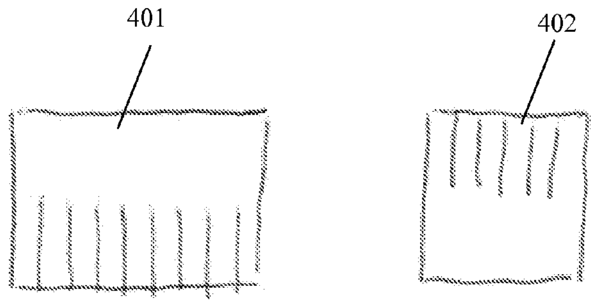


FIG. 4b

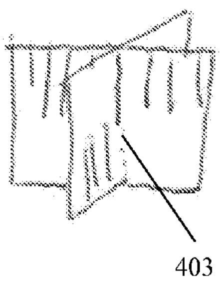


FIG. 4c

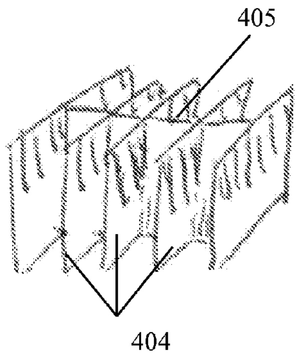
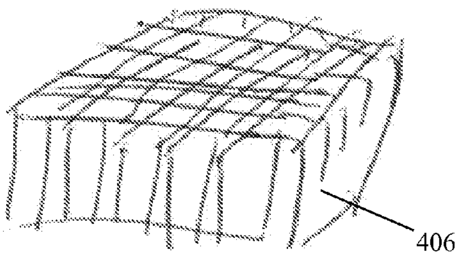


FIG. 4d



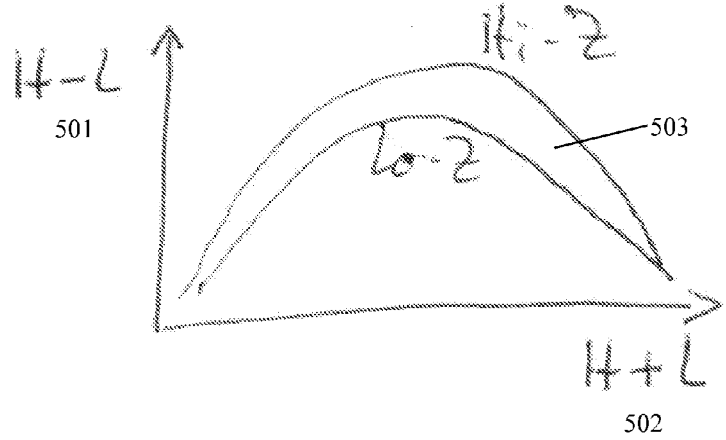


FIG. 5

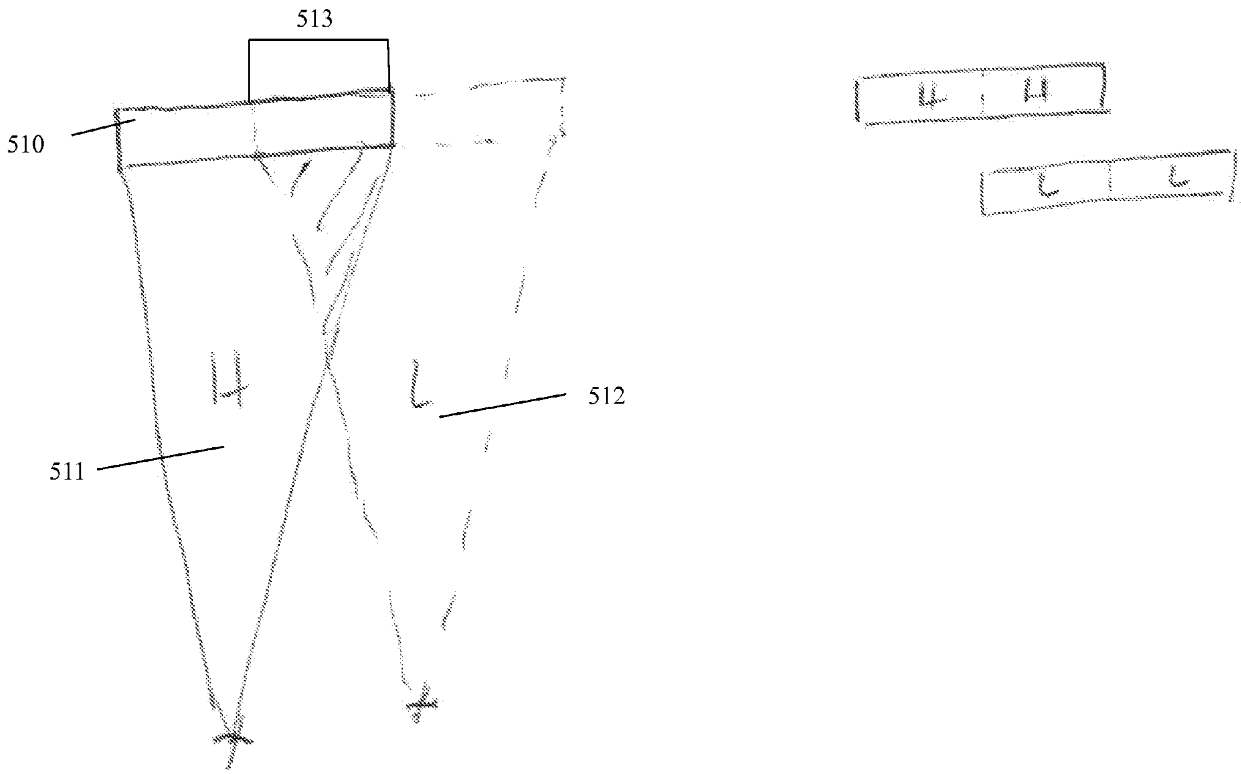


FIG. 5a

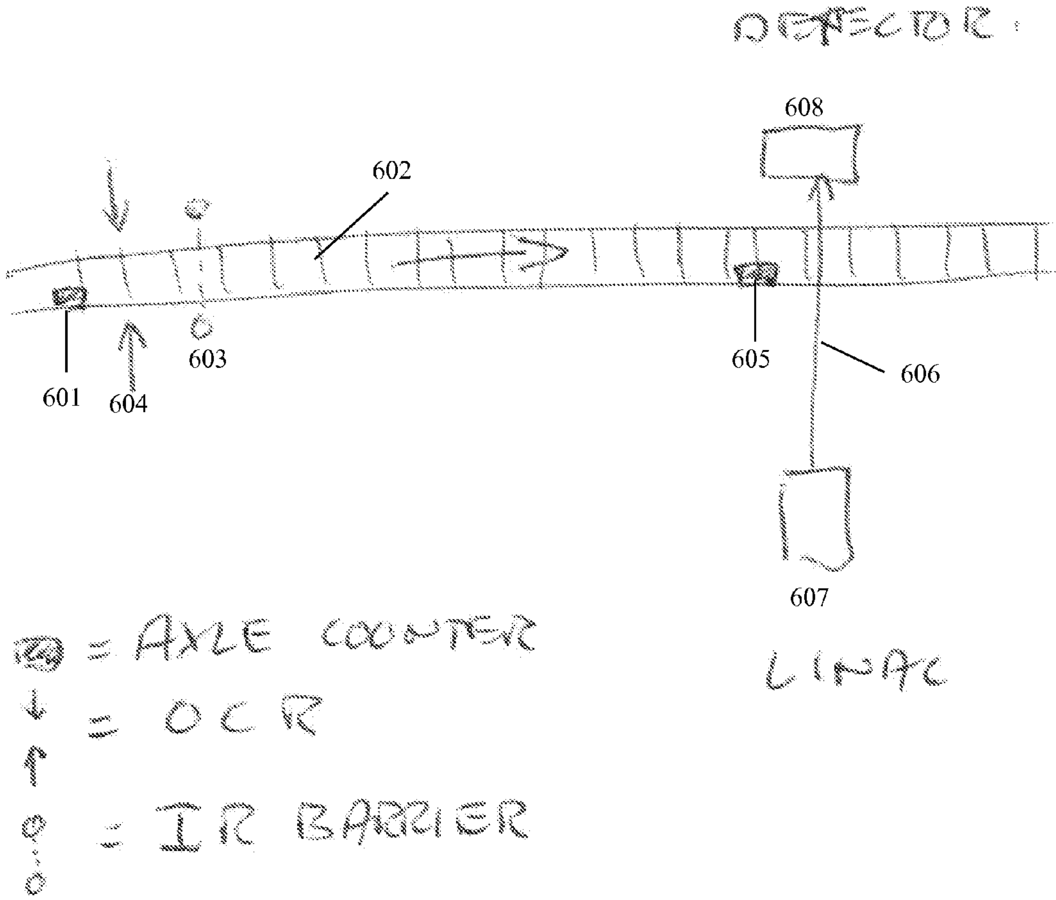

DETECTOR
608
602
603
601
604
605
606
607
= AXLE COUNTER
= OCR
= IR BARRIER
LINAC

FIG. 6

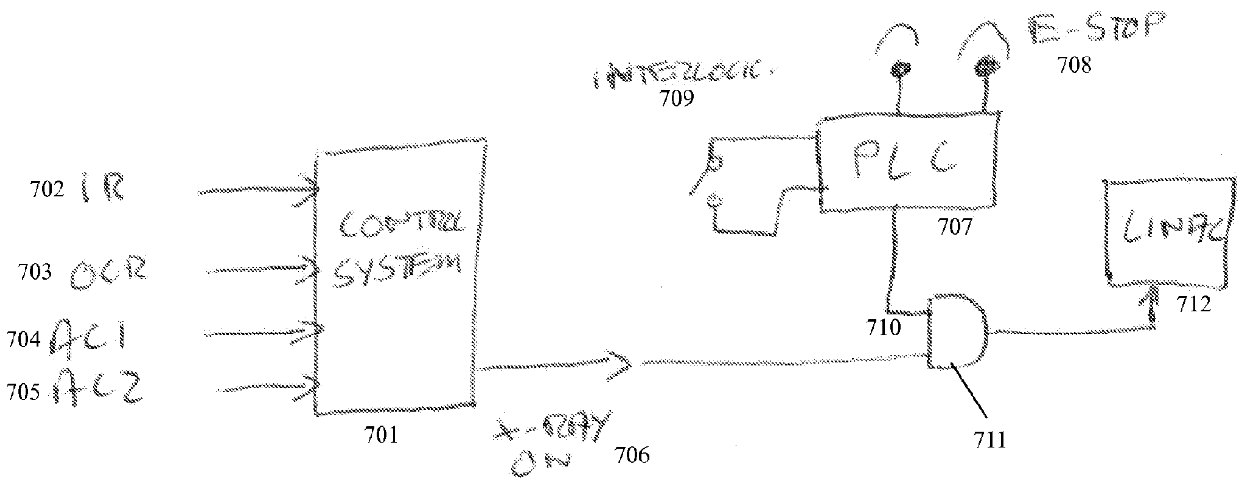

702 IR
703 OCR
704 AC1
705 AC2
CONTROL SYSTEM
701
X-RAY ON
706
INTERLOCK
709
PLC
707
E-STOP
708
710
711
LINAC
712

FIG. 7

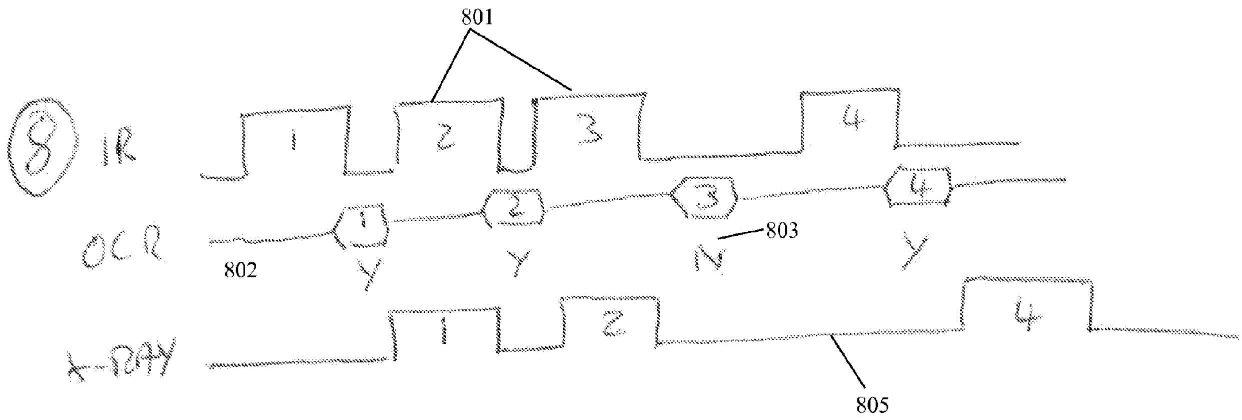


FIG. 8

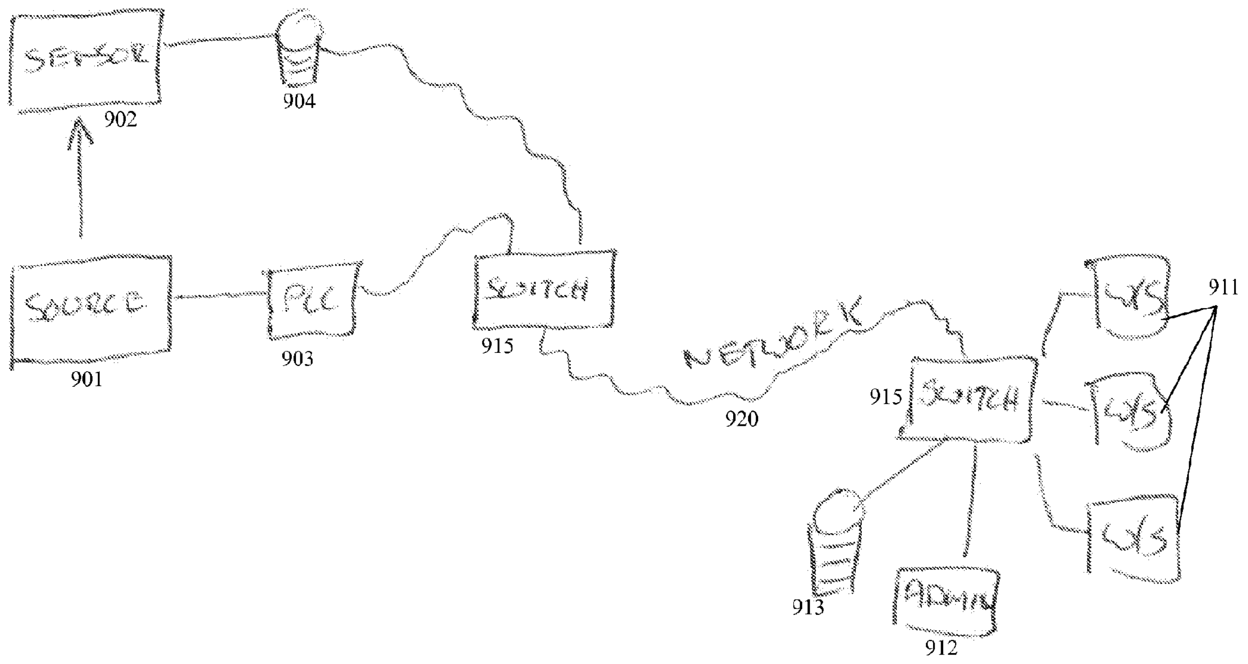

SENSOR
902
904
SOURCE
901
PLC
903
SWITCH
915
NETWORK
920
915
SWITCH
W/S
W/S
W/S
911
913
ADMIN
912

FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20110038453 A **[0010]**