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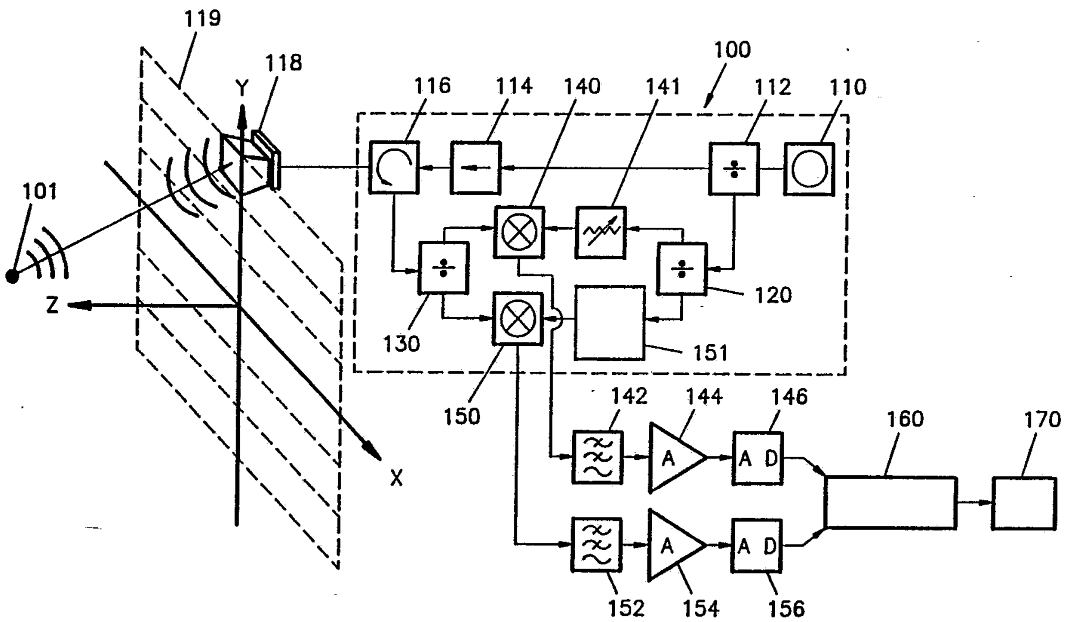

(57) Abstract

A holographic surveillance system including means for generating electromagnetic waves; means for transmitting the electromagnetic waves toward a target at a plurality of predetermined positions in space; means for receiving and converting electromagnetic waves reflected from the target to electrical signals at a plurality of predetermined positions in space; means for processing the electrical signals to obtain signals corresponding to a holographic reconstruction of the target; and means for displaying the processed information to determine nature of the target. The system uses electromagnetic waves at a frequency and amplitude adapted to penetrate a material between the target and the means for transmitting.

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HIGH RESOLUTION HOLOGRAPHIC SURVEILLANCE SYSTEM

STATEMENT OF GOVERNMENT INTEREST

This invention was made with Government support under Contract DE-AC06-76RLO 1830 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

FIELD OF THE INVENTION

The present invention relates to a method and apparatus useful for inspection of concealed objects. The method and apparatus have particular utility for personnel inspection in mass transportation centers.

BACKGROUND AND RELATED ART

The need for a new and more versatile personnel inspection system in mass transportation centers has increased in recent years. Traditional inspection systems such as metal detectors and x-ray imaging systems have limitations and adverse effects in the detection of concealed targets. The limitations on metal detectors are that they cannot determine the precise location of the concealed threat on suspects and have the inability to detect plastic concealed weapons. An additional limitation to the metal detector involves the fact that it has varying degrees of sensitivity to different metals and, therefore, possible nondetection of metal weapons. X-ray imaging of personnel is limited by radiological health considerations. Consequently, an alternative or complementary approach to personnel inspection is needed.

Related art known to the inventors includes the following. A report, Evaluation of Passive Far Infrared Radiometric Techniques for Detection of Concealed Objects; Hodges, D.T. et al.; Aerospace Report No. ATR-79(7745)-1, Contract No. At-(29-1)789; Sandia Laboratories, Albuquerque, NM, 87115; March 1979, p. 41, discloses apparatus and a process for far infrared detection of concealed objects. U.S. Pat. No. 4,841,489 to Ozaki et al. discloses a method for imaging an object or substance by ultrasonic or electromagnetic waves based on a synthetic aperture method capable of economizing memory capacity, achieving real time base image reproduction and obtaining a high quality image.

The invention disclosed herein involves a new inspection technique that uses millimeter wave holography above about 26.5 GHz. This frequency region is ideally suited for personnel inspection because the radiation easily penetrates clothing and does not present a health hazard. Furthermore, the holographic technique can provide high resolution on the order of about 1.13 cm at 26.5 GHz, and 0.27 cm at 110 GHz. With these resolutions, target identification and location are possible.

An object of the invention is to provide high resolution target identification and location on a suspect and/or an electronic frisk of a suspect without the suspect's knowledge. It is a further object of the invention to provide a surveillance system that is not easily circumvented. A further object of the invention is to provide additional surveillance capability in near real-time at personnel check points. A yet further object of the invention is to provide a detection system that can find anomalies on possible suspects that is not sensitive to different metal types and can detect nonmetal weapons such as those made of plastic.

BRIEF DESCRIPTION OF THE INVENTION

A general embodiment of the invention provides for a holographic surveillance apparatus that includes means for transmitting electromagnetic waves toward a target; means for receiving electromagnetic waves reflected from the target; means for processing the received electromagnetic waves to obtain information for constructing a holographic image; and means for displaying the holographic image. An optional video means for optically monitoring the target may be used.

Another embodiment of the invention provides for a holographic surveillance apparatus comprising means for generating electromagnetic waves; means for transmitting the electromagnetic waves toward a target at a plurality of predetermined positions in space; means for receiving and converting electromagnetic waves reflected from the target to electrical signals at a plurality of pre-determined positions in space; means for processing the electrical signals to obtain signals corresponding to a holographic reconstruction of the target; and means for displaying the processed information to determine the characteristics of the target. A yet further embodiment provides for the means for transmitting and means for receiving electromagnetic waves to include antenna means of a plurality of antenna arranged in a linear array; and mechanical scanner means for moving the linear array during transmission and receipt of the electromagnetic waves. Another embodiment provides for the means for transmitting and means for receiving electromagnetic waves to comprise a two dimensional antenna array. A yet further embodiment provides for the means for processing the received information to comprise means for extracting phase and amplitude information from the electrical signals; means for storage of the phase and amplitude information; and means for processing the stored information to obtain signals corresponding to a holographic reconstruction of the object. Another embodiment provides for apparatus wherein the means for transmitting is capable of generating electromagnetic waves at a frequency and amplitude adapted to penetrate a material between the target and the means for transmitting. Also included is an optional embodiment where the apparatus comprises a video means for optically monitoring the target.

Another general embodiment of the invention provides for a method for detecting objects comprising the steps of providing a holographic surveillance apparatus; transmitting electromagnetic waves with the apparatus toward a target material located between a suspected concealed object and the apparatus, at a frequency and amplitude adapted to penetrate the material so as to reflect from the object and/or the material and return, and wherein the frequency provides sufficient resolution to allow identification of at least the presence of the object; receiving the reflected electromagnetic waves; processing the received electromagnetic waves to obtain signals corresponding to a holographic reconstruction of the material and/or object; and displaying the holographic reconstruction.

A yet further embodiment of the invention includes a method for detecting objects comprising transmitting electromagnetic waves from a plurality of positions in space (x,y) and toward a target at z where an object is suspected; detecting the reflected electromagnetic waves from the target at a plurality of positions in space (x,y); converting the detected waves to signals containing phase and amplitude information, f(x,y,z); computing the two dimensional Fourier transform of f(x,y,z) to obtain F(u,v,z) at z=0; multiplying the Fourier transform by the complex backward wave propagator

$$\exp\left\{\frac{2\pi j}{\lambda}\left[1-(\lambda u)^2-(\lambda v)^2\right]^{1/2}(z'-z)\right\}$$

where z'-z is the distance from the transmitting position to the target; computing the inverse transform of the result in step (d) yielding f(x,y,z'); computing the target intensity image $|f(x,y,z')|^2$; and displaying the resultant focused image information. A further embodiment of the method includes obtaining different focused images at planes z*, by changing the z' value to vary the distance to the target in step (e). The phase and amplitude information, f(x,y,z), may be temporarily stored prior to computing the Fourier transform in step (c). The intensity image $|f(x,y,z')|^2$ may stored for later viewing.

The above embodiments of the invention are contemplated to operate at frequencies above 26.5 GHz, preferably between about 26.5 GHz and about 110 GHz, and most preferably between about 35 GHz and about 95 GHz.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a semischematic diagram of one embodiment of the invention depicting a simplified scanned, one element, millimeter wave holographic system.

FIG. 2A shows an optical picture of a mannequin with a metal gun beneath a cotton/acetate suit jacket.

FIG. 2B shows the mannequin imaged with a simulated holographic linear array at 35 GHz.

FIG. 3A illustrates the 35 GHz imaging setup used for FIGS. 3C and 3D.

FIG. 3B is an optical picture of a handgun with a plastic handle (model Glock 17).

FIG. 3C is an holographic image at 35 GHz of the same handgun in air with no other intervening barrier material.

FIG. 3D is an holographic image at 35 GHz of the same handgun imaged through two layers of clothing at 35 GHz.

FIG. 4A illustrates the 90 GHz imaging setup used for FIGS. 4C and 4D.

FIG. 4B is an optical picture of the same handgun as in FIG. 3B.

FIGS. 4C-D are holographic images of the same handgun as in FIGS. 3C-D, imaged through the same two barrier materials, but with a 90 GHz holographic system.

FIG. 5 shows one embodiment for the millimeter wave holographic surveillance system.

FIG. 6 shows a block diagram of a preferred embodiment of the invention.

FIG. 7 shows the arrangement of interconnections of the computer and various control points in the overall system.

FIGS. 8A, 8B, and 8C depict an embodiment of a mechanical scanner useful in monitoring travelers at transportation centers such as airports.

FIG. 9 shows the arrangement of the waveguides on the front of the antenna array.

FIG. 10 shows a side view, A, and top view, B, of a typical antenna useful at 35 GHz.

FIG. 11 shows the arrangement of the 128 antenna on the antenna array 618.

FIG. 12 shows the timing sequence for the individual channels of the multiplexed switching tree.

DETAILED DESCRIPTION OF THE INVENTION

The fundamental process of holography is its ability to construct a diffraction lens for each point on the target. If we have a complex body or target consisting of a multitude of points, the hologram is then the superposition of these individual diffraction lenses. Essentially, a coded diffraction pattern capable of defining the target's wave reflection or scattering characteristics for each viewed aspect angle.

Millimeter wave holography is a wavefront reconstruction utilizing both phase and amplitude measurements of the radiation scattered from the target. In contrast to conventional imaging, where the outcome is a two-dimensional slice through the object, three-dimensional information can be recorded by holography since the phase of the radiation is a linear function of distance traveled. Once the two-dimensional distribution of phase and amplitude of the scattered wave has been measured and recorded, it can be back propagated or forward propagated, as will be shown below. Consequently, an image of any desired plane away from the aperture may be computed and displayed.

Millimeter wave holography obtains its resolving power by a synthetic aperture technique. The effective resolution is as though an antenna the size of the scan aperture had been used; and since this can be very large, very good resolution is obtained. Additionally, a hologram behaves as though it were obtained using a large antenna focused at all ranges simultaneously. That is, the focal plane is not fixed as in the case of the focused lens imaging system. Therefore, visualization in three dimensions is possible from a single hologram. The image exists in three-dimensional space and can be examined by displaying it plane by plane, or stacking the planes in an isometric display.

As an example, consider the simplified scanned -- one element -- millimeter wave holographic transceiver system 100 shown in FIG. 1. Oscillator 110 provides the millimeter wave source energy signal for detecting the target and for reference signals. In this example the oscillator 110 is a continuous wave, coherent source. Signals from the oscillator 110 are divided by the first power divider 112 so that part of the signal is sent to the second power divider 120 for use as a reference signal in the balanced mixers 140,150, with the remainder of the signal transmitted to the isolator 114. The isolator 114 is a rectifying device that is able to transmit millimeter waves in one direction (arrow), but not in the other. This allows millimeter waves to be sent to the circulator 116 but prevents their return to the oscillator 110 which would impair its operation. Circulator 116 allows the millimeter waves from the oscillator 110 to be transmitted to the single horn transceiver antenna 118, but not to the third power divider 130. Millimeter waves from the holographic transceiver 100 are radiated by the antenna 118. The antenna 118 transmits the millimeter waves to the target and also receives the targets reflected waves.

The phase and amplitude data from the received waves is then sent to the holographic processor (computer) 160 as described below.

Note that the illustration embodied in FIG. 1, is only a single element system where the antenna 118 is scanned in an X-Y scanner 119 to fill the aperture. In a multi-antenna linear array system, the array would be mechanically scanned in one direction (e.g. vertical) and electronically scanned in the other (e.g. horizontal). Further, in a multi-antenna planar array system, the array would be electronically scanned in both directions.

Thus, target 101 is illuminated by a source of radiation from antenna 118. The point reflector, target 101, reflects millimeter waves that emanated from the antenna 118 back to the same antenna 118. For the single element antenna system shown in FIG. 1, let the transceiver 100 scanning over the $(x,y,z = 0)$ plane 102 receive the reflected signal from a point (x_o,y_o,z_o) on the target with antenna 118.

The received signal can be written as

$$E_o(x,y) = A(x_o,y_o,z_o) \cos[\omega t + \phi_o(x,y)] \qquad (1)$$

where ω = radian frequency
r = distance from the antenna to the object point,

written as

$$r = \sqrt{(x-x_o)^2 + (y-y_o)^2 + z_0^2}$$

$$\phi_o(x,y) = \frac{2\pi}{\lambda} r(x,y) = \text{phase of target}$$

and

A = reflected amplitude of the target point.

The received signal is sent to a circulator 116 that allows the signal from waves reflected from the target to be sent to the third power divider 130, but not toward the millimeter wave oscillator 110. When the signal reaches the power divider 130, it is equally split into two channels. One channel is called the in-phase "I" leg 140+ and the other is the quadrature "Q" leg 150+. Thus the signal enters balanced mixers 140,150 which detect the phase and amplitude of the signal. Balanced mixer 140 is referenced to the oscillator signal from the second power divider 120, in phase, by signal attenuator 141. The other balanced mixer 150 is referenced to the oscillator signal from the second power divider 120, in quadrature (90°), by phase shifter 151. The signal attenuator 141 is used to adjust the amplitude of the signal in the in-phase leg at the balanced mixer 140. This power adjustment capability is necessary because the power of the balanced mixer in the quadrature leg is decreased due to the phase shifter 151. In addition, for optimum operation, the local oscillator signal power must be the same at the balanced mixers 140,150.

Signals from the balanced mixers 140,150 are then further processed by low pass filters 142,152. The output from the balanced mixers 140,150 is the sum and difference of the frequency of the local oscillator 110 and the signal reflected from the target 101. Additionally, phase information of the reflected signal referenced to the oscillator is also sent on to computer 160. Since the frequency of the oscillator and reflected target signal are the same, the sum of the two frequencies is two times the oscillator frequency and the difference is zero. However, phase information is in both the sum and the difference frequencies. It is easier electronically to extract the amplitude and phase information from the difference frequency than the sum frequency, because the sum frequency is a very high frequency. The low pass filters 142,152 thus pass the difference frequency with its phase information on to operational amplifiers 144,154. Operational amplifiers 144,154 are used to increase the gain of the in-phase "I" and quadrature "Q" signals. The gains of the operational amplifiers 144,154 are set to match the maximum range of the analog to digital (A/D) converters 146,156. The A/D converters 146,156 change the analog in-phase and quadrature signals from the operational amplifiers 144,154 to 12 bit digital signals. Digital information from the in-phase and quadrature signals from the A/D converters 146,156 is processed by a digital-holographic-reconstruction system as computer 160 that converts the information to a form allowing visual display of the holographic image on video display 170.

Proceeding with the mathematical computation after low pass filtering, the result is the real $S_R(x,y)$ and imaginary $S_I(x,y)$ values of the complex signal. That is,

$$\begin{aligned} S_R(x,y) &= A(x_o,y_o,z_o)\cos\phi_o(x,y) \\ S_I(x,y) &= A(x_o,y_o,z_o)\sin\phi_o(x,y) \end{aligned} \qquad (2)$$

Thus, both amplitude of the reflected signal and distance to the target point have been preserved. They can be independently extracted by the operations

$$A(x_o,y_o,z_o) = |S_R(x,y) + iS_I(x,y)| \qquad (3)$$

$$r(x,y) = \frac{1}{\beta}\tan^{-1}\left(\frac{S_I}{S_R}\right) = \frac{\phi_o(x,y)}{\beta}$$

where ϕ = phase and $\beta = \frac{2\pi}{\lambda}$

By superposition, one can argue that the target can be made up of a large number of points, and that the signal at (x,y) is a summation of individual reflections. Thus, if the x-y plane 102 is fully scanned, and S_R, S_I is measured and recorded, everything about the reflectivity of the target is preserved.

A further example considers the case where Equation (2) is written in more general terms. An antenna is scanned in some plane (x,y) 102 where z = constant, and the wavefront reflected from a target is recorded. The equation is written as

$$f(x,y,z) = g(x,y,z)\ \exp[j\phi_o(x,y,z)] \qquad (4)$$

where g = amplitude
and ϕ_o = phase of the wave as a function of position.

Since the radiation obeys the rules of wave theory, it is necessary that the recorded wave be propagated according to the same rules in order to retrieve the wavefront in its original position in space. The angular spectrum method simply decomposes the recorded wavefront into individual plane waves propagating in different angular directions (see Goodman, J. W.; 1968; <u>Introduction to Fourier Optics</u>; McGraw-Hill). The process of propagation induces a phase change on each plane wave as it propagates from one plane to the next. The composite wave can then be reconstructed by vector summation of the plane wave components. Computer 160 then calculates the wave at the z' plane; i.e., f(x,y,z'). The two-dimensional Fourier transform of f(x,y,z), gives

$$F(u,v,z) = \iint f(x,y,z)\ \exp[-2\pi j(ux+vy)]dxdy \qquad (5)$$

and conversely,

$$f(x,y,z) = \iint F(u,v,z)\ \exp[2\pi j(ux+vy)]dudv \qquad (6)$$

In propagating from the z plane to a z' plane, f must obey Helmholtz's equation

$$\nabla^2 f + \left(\frac{2\pi}{\lambda}\right)^2 f = 0 \qquad (7)$$

Inserting Equation (6) into Equation (7), one obtains

$$\iint \left\{ \frac{\partial^2 F}{\partial (z'-z)^2} + \left[\left(\frac{2\pi}{\lambda}\right)^2 - (2\pi u)^2 - (2\pi v)^2 \right] F \right\} \cdot \{\exp[2\pi j(ux+vy)]\} dudv \qquad (8)$$

This relation holds for all x,y if

$$\frac{\partial^2 F}{\partial (z'-z)^2} + \left(\frac{2\pi}{\lambda}\right)^2 [1-(\lambda u)^2 - (\lambda v)^2] F = 0 \qquad (9)$$

The solution to this equation is

$$F(u,v,z') = F^+(u,v) \exp\left\{\frac{-2\pi j}{\lambda} [1-(\lambda u)^2 - (\lambda v)^2]^{1/2} (z'-z)\right\} + F^-(u,v) \exp\left\{\frac{2\pi}{\lambda} [1-(\lambda u)^2 - (\lambda v)^2]^{1/2} (z'-z)\right\} \qquad (10)$$

where F^+ represents the Fourier transform (angular spectrum) of the wave propagating toward the far field,

and

F^- represents the Fourier transform (angular spectrum) of the wave propagating from the received plane (z=0) back towards the target.

NEAR-FIELD MILLIMETER IMAGE

For radiation in the backward direction (i.e., towards the target), one sets $F^+ = 0$. Then using initial conditions, one finds $F^-(u,v) = F^-(u,v,z)$ and

$$F^-(u,v,z') = F^-(u,v,z) \exp\left\{\frac{2\pi j}{\lambda} [1-(\lambda u)^2 - (\lambda v)^2]^{1/2} (z'-z)\right\} \qquad (11)$$

Taking the inverse Fourier transform, one obtains the target image

$$f(x,y,z') = \iint F(u,v,z)\ \exp\left\{\frac{2\pi j}{\lambda}\,[1-(\lambda u)^2-(\lambda v)^2]^{1/2}(z'-z)\right\}\cdot \tag{12}$$

$$\exp\{2\pi j(ux+vy)\}dudv$$

Thus, in summary, if one knows the target's scattering wave field (i.e., near-field) in one plane, one can calculate the field at the target by:

(1) Computing the two-dimensional Fourier transform of the given field f(x,y,z) (i.e. scan over the aperture and get the phase and amplitude information);

(2) Multiplying the Fourier transform by the complex backward wave propagator

$$\exp\left\{\frac{2\pi j}{\lambda}\,[1-(\lambda u)^2-(\lambda v)^2]^{1/2}(z'-z)\right\}$$

where z'-z is the distance from the antenna array to the target, if desired different focus planes z* may be calculated, to obtain the optimum viewing image, by changing the z' value to vary the distance to the target;

(3) Computing the inverse transform of the result yielding f(x,y,z'), this plane is different from that in (2); and

(4) Computing the target intensity image $|f(x,y,z')|^2$ and plotting the results (e.g. viewing screen).

The algorithm operations described above are performed on the received signals by the computer and converted for video display. The resultant high resolution image uniquely identifies the scattering points on the target and readily identifies the target.

EXAMPLE 1

FIG. 2a shows an optical picture of a mannequin with a pellet gun, completely of metal, beneath a cotton/ acetate suit jacket that was used as the target subject. FIG. 2b shows the mannequin imaged with a simulated holographic linear array at 35 GHz. The cotton/acetate jacket is easily penetrated by the millimeter waves and the metal pellet gun is readily detected. A holographic linear array (as well as a planar array) was simulated mechanically by physically moving the single antenna 118 of FIG. 1 with an X-Y scanner 119 in the x-y plane, to different positions about one-fourth wavelength apart, until an acceptable image as shown in the FIGS. 3C-D was obtained. The results were summed and stored in the computer 160 as if an antenna 118 were located at each position. The number of positions in the x direction was 256 and the number in the y direction was 256, or a total of 65,536 positions of the antenna. This scan required approximately 5 minutes and reveals the time limitations of using a single element antenna where both the x and y axis must be mechanically scanned. Thus, linear antenna arrays or planar antenna arrays as further discussed herein are preferred.

EXAMPLE 2

FIG. 3a illustrates the test setup used for FIGS. 3c and 3d. The 35 GHz holographic transceiver system 300 is similar to the one discussed in FIG. 1. Leads 310,320 carry the in-phase and quadrature signal information respectively to the computer 160. Horn antenna 330 in a monostatic system as in FIG. 1 using an X-Y scanner 119 was used to transmit and receive the 35 GHz signal. An image was obtained as in Example 1. However, instead of using a mannequin, an optically opaque barrier of clothing 340 placed 18 cm from the antenna 330, comprised of a first layer of 100 percent heavy wool 341 and a second layer of 100 percent light polyester 342, was used to hide a Glock (model 17) handgun 350 having a plastic handle. FIG. 3b is an optical picture of the handgun 350. FIG. 3c is a holographic image of the handgun 350 in air without the clothing 340. FIG. 3d shows the handgun 350 imaged through the two layers of clothing at 35 GHz. A comparison between the handgun 350 imaged in air and behind the clothing reveals that little or no degradation occurs due to the clothing 340.

EXAMPLE 3

FIG. 4a illustrates the test setup used for FIGS. 4c and 4d. The 90 GHz holographic transceiver system 300 is similar to the one discussed in FIG. 1. Leads 410,420 carry the in-phase and quadrature signal information respectively to the digital holographic reconstruction system and visual display. Horn antenna 430 in a monostatic system was used to transmit and receive the 90 GHz signal. An image was obtained as in the method of Example 2. Distance between the horn antenna 430 and the clothing 340 was 18 cm. FIG. 4b is an optical picture of the handgun 350. FIG. 4c is an holographic image of the handgun 350 in air. FIG. 4d shows the handgun 350 imaged through the same two layers of clothing 340 as in FIG. 3d. Again, little degradation occurs due to the barrier materials, however, the holographic images at 90 GHz show much better resolution than the 35 GHz system.

FIG. 5 shows an integrated, linear millimeter-wave, holographic, surveillance system 500. FIG. 5 shows the main system components for detecting weapons or other items under clothing barriers or in carry on items such as luggage. In the operation of one embodiment of the invention an individual 501 is optionally monitored by one or more video cameras 520. The video camera 520 may be of the typical surveillance type. The purpose of the optional video camera 520 is to identify and/or record an individual's optical image and match it with the holographic image. This is helpful since the holographic images at the frequencies between 26.5 to 110 GHz do not have high enough resolution to distinguish the details of the human face. At the same time the individual is monitored with millimeter waves emanating from a transceiver 530 within scanner 550. The transceiver 530 is shown having a horizontal linear antenna array and the scanner 550 would move the transceiver 530 vertically to complete a scan. The transceiver 530 is thus scanned mechanically in a vertical direction and scanned electronically horizontally.

Signals from the transceiver 530 are sent to computer means such as the computer system 560. The computer system 560 performs the holographic algorithm discussed above and the digital holographic reconstruction. Finally, the video display 570 shows a visual image 571 and a holographic image 572 of the individual along with any concealed items such as weapons.

Materials through which the apparatus is able to scan and provide detection of concealed objects includes the low loss tangent dielectric materials such as clothing, plastics, natural and processed plant materials (such as woven materials, wood, leather, and the like), glass, epoxies, kevlar, and the like. With the preferred system of the invention, an individual can be inspected in less than two seconds.

Materials readily capable of detection are those whose relative dielectric constant is larger than the barrier which they are behind, provided the barrier has losses low enough to permit the signal to penetrate and return. Materials whose relative dielectric constants are lower than the barrier materials may also be detected indirectly by shadowing due to other surrounding materials having higher relative dielectric constants. When high loss barriers, e.g., high relative dielectric constant (conductors), are encountered they can be detected and the contents behind or in them inspected manually.

EXAMPLE 4

A presently preferred embodiment of the linear holographic surveillance system 500 is shown in FIGS. 6-12. Referring to FIGS. 6 and 7 there is shown the interconnection of the transmit/receive electronics 601 with switching means such as multiplexed switching tree 617, the computer system 560, and logic board 710. The transceiver 530 is comprised of all but the computer system 560 and video display 570 of FIG. 6. The transceiver is a monostatic receiver that provides in-phase and quadrature amplitude and phase data in either continuous wave or pulse modes of operation. The transceiver 530 is preferably of waveguide component type construction and is interfaced with the multiplexed switching tree 617. The transmit/receive electronics 601 are shown within the dashed lines. Specifications for various critical components of the transceiver 530, scanner 550, and computer system 560 for a 35 GHz system are specified below.

Oscillator 610 provides the millimeter wave source energy signal for detecting the target and for reference signals. It is preferred that the oscillator 610 is a high Q cavity design with low noise spectrum output. The oscillator frequency is preferably 35 GHz +/- 0.5 GHz with a temperature drift below about 0.160 MHz/°C. Output power should be sufficient to provide at least 50 mW at the antenna output. Signals from the oscillator 610 are sent to a first isolator 611 and are then divided by the first power divider 612 so that part of the signal is sent to a 90-degree power divider 620 through first variable attenuator 613 for use as a reference signal in the double-balanced mixers 640,650, with the remainder of the signal transmitted to a second isolator 614. 90-degree power divider 620 provides equal amplitude "local oscillator" drive signals to the double first and second double-balanced mixers 640,650 in quadrature (i.e. 90 degree phase difference). The amplitude and phase accuracy must be good enough to allow precise adjustment of amplitude balances with the trim attenuator 641, and phase in quadrature with the trim phase shifter 651. When mounted on a mechanical scanner the trim attenuators should be lockable and not subject to change due to acceleration or deceleration forces. The isolators 611,614 are rectifying devices able to transmit millimeter waves in one direction (arrow), but not in the other, and should have an isolation of at least 20 dB. The first power divider 612 should have a coupling factor adequate to drive the double-balanced mixers 640,650 "local oscillator" port to a level that provides maximum dynamic range. First variable attenuator 613 is used to select the ideal signal level to the double-balanced mixers 640,650. Output from the second isolator 614 is coupled to a second variable attenuator 615 which is preferably calibrated and has an attenuation range of at least 50 dB. The output of the second variable attenuator 615 is coupled to a multiplexed switching tree 617 by a first single pole double throw SPDT-switch 616 which is controlled by the logic board 710. The switches in the multiplexed switching tree 617 are arranged and controlled so that the source power from the transceiver 530 can be routed to any waveguide and its associated antenna in a sequential fashion. The switches are driven by TTL-compatible switch drivers 720. The switch drivers 720 are addressable in a binary fashion so that they may be driven from a binary counter through logic board 710, where the counter output corresponds to the selected antenna. The 128 leads from the output of the binary switch array 617A are interfaced to waveguides 901 on the antenna array 618.

Millimeter waves from the transceiver 530 are radiated by the antenna array 618. The antenna array 618 transmits the millimeter waves to the target and also receives the targets reflected waves. The phase and amplitude data from the received waves is processed and sent to the computer system 560. Thus the target is illuminated by a source of radiation from antenna array 618. In the simple system shown in FIG. 1, the target was mechanically scanned horizontally and vertically by physically moving the antenna to the different positions in the x and y axis. In the presently preferred multi-element (antenna) linear array system, the antenna array 618 on transceiver 530 is electronically scanned in the horizontal direction and mechanically scanned in the vertical direction.

Referring again to FIG. 6, the switching means is preferably a set of two SPDT-switches 616,626 and a dual multiplexed switching tree 617 such as a dual set of binary switching trees, which is comprised of switches 617C in a first and second binary switch array 617A,617B that directs outgoing millimeter wave signals to the appropriate antenna 1001 of the 128 element antenna array 618. Six layers of switches 617C are needed in each of the binary switch arrays 617A,617B to obtain the required 64 outgoing/incoming channels in the upper antenna array 903 and 64 channels in the lower antenna array 904 of antenna array 618. In FIG. 6 only some of the required switches 617C in binary switch arrays 617A,617B are shown as this concept is well known to those skilled in the art. Switches 617C in the binary switch arrays 617A,617B are preferably pin switches when using first and second SPDT-switches 616,626. While a binary switching means has been described above, other switching means such as for example a comb-type transmission-line-sequential switching array with appropriate wiring and control adjustments can also be used.

With further reference to FIG. 6 and also to FIG. 9, the multiplexed switching tree 617 is controlled by the computer system 560 with commands through logic board 710 that controls switch drivers 720 and first and second binary switch arrays 617A,617B respectively. The computer system 560 initiates the sequence with a signal at the start signal 701, which begins sequencing the signals by the clock/array select board 709. Both SPDT-switches 616,626 are single pole double throw switches controlled from the logic board 710. Both SPDT-switches 616,626 are appropriately timed so that when first SPDT-switch 616 is "on" for binary switch array 617A (and "off" for binary switch array 617B), then second SPDT-switch 626 is "on" for binary switch array 617B (and "off" for binary switch array 617A). Thus when either SPDT-switch 616,626 is "on" for outgoing signals to the upper antenna array 903 the other SPDT-switch will be "on" to incoming signals from the lower antenna array 904, and vice versa. The reflected return signal is detected by the antenna array 618 and is sent to the binary switch array 617B and appropriately switched to second power divider 630, but not toward the second variable attenuator 615 by first and second SPDT-switches 616,626. Interference between the incoming signals and outgoing signals is prevented and improved separation attained by transmitting on one channel and simultaneously receiving on another channel. The preferred sequence is to sequentially transmit across the upper 64 channels (numbers 1-64 in FIG. 9) of upper antenna array 903 while simultaneously sequentially receiving return signals with the lower 64 channels (numbers 65-128 in FIG. 9). Thus, when transmitting through upper antenna channel 1 with binary switch array 617A, signals are simultaneously received through lower channel 65 with binary switch array 617B. When transmitting with upper channel 2 reception is through lower channel 66 and so on. On the other hand, when transmitting through lower antenna channel 65 reception is through upper channel 1, and when transmitting through lower channel 66 reception is through upper channel 2 and so on.

Referring again to FIG. 6, the second power divider 630 is the input for the first and second balanced mixers. When the incoming signal reaches the second power divider 630, it is equally split into two channels to drive the "radio frequency" ports of the double-balanced mixers 640,650. The path length between the second power divider 630 and each double-balanced mixers 640,650 should be about equal to keep phase differences to a minimum. One channel is called the in-phase leg 640+ and the other is the quadrature leg 650+. Thus the signal enters double-balanced mixers 640,650 which detect the phase and amplitude of the signal. The double-balanced mixers 640,650 should be a matched pair selected for minimum conversion loss (less than 4.5 dB) and maximum dynamic range. First double-balanced mixer 640 is referenced in phase to oscillator 610 by 90-degree power divider 620 through trim attenuator 641. The second double-balanced mixer 650 is referenced to the oscillator signal from the 90-degree power divider 620 in quadrature (90 degrees) through trim phase shifter 651. For optimum operation, the local oscillator signal power must be the same at the double-balanced mixers 640,650. Signals from the double-balanced mixers 640,650 are then further processed similarly to the process described for FIG. 1 by operational amplifiers 644,654 and converted to digital form in A/D converter board 669 for further computation by computer system 560 and viewing on the video display 570. Low frequency filters may not be needed before the operational amplifiers 644,654 (see FIG. 1), if there is enough inductance in the circuits to remove the 35 GHz signal prior to this point.

Referring now to FIG. 7, which shows details of the interconnection of the computer system 560 with drive system of scanner 550 and transceiver 530. Computer means 661 such as a Computer System SUN 4/370 GX 661 is used for control and calculations for reconstruction of the holograms. This computer is a reduced Instruction Set (RISC) computer with a bus interface 662A, a VME bus 663, has 32 Mbytes of memory and a 670 Mbyte hard drive. An array processor 664, such as a Skybolt array processor, based on the Intel 860 and 960 chip set, having a maximum speed capability of about 80 Mflops is used to accelerate the math operation discussed in the holographic algorithm above. A start signal 701 is sent to the clock/array select board 709 for initiating and controlling the sequence to the logic board 710. A return data valid signal 702 is used to confirm that data from the "I" and "Q" channels are ready to be received by the A/D converter board 669. The logic board 710 determines which channel is "on" in the antenna array 618. The encoder 835 provides the computer system 560 the vertical position where the holographic array assembly is on the scanner 550. The computer system 560 determines when a horizontal scan is necessary and sends the start signal 701 to initiate the scanning process. The antenna array 618 is sequentially scanned to the individual waveguides 901 first through the upper antenna array 903 and then the lower antenna array 904. The data from each channel is sent back to the computer system 560 through the multiplexed switching tree 617 as discussed above. After scanning through the upper and lower antenna array 903,904 once, the scanning is stopped and the transceiver 530 waits for the next "start" command from the computer system 560 when it is in its next appropriate vertical position on the scanner 550. If desired, scanning can be initiated at the lower array rather than the upper array.

The A/D converter board 669 is a high speed analog input board for the VME bus 663 with associated A/D software driver. It is used to capture the analog amplitude and phase information signals from the transceiver 530 and convert them to digital form. The timer/counter board 665 for the VME bus 663 is used to control the timing sequence for the transceiver 530 based on positional information provided by the encoder. Video board 666 provides a high resolution frame grabber and is used for displaying an optical picture obtained from video camera 520 on an optional video display 570 that preferably provides a visual image 571 along with a 35 GHz holographic image 572 of an individual. Frame buffer 662B interfaces the computer with the video display 570 that may consist of a visual image 571, a holographic image 572 or other output means. The servomotor 830 on the scanner 550 is controlled by motor driver 831 and motor indexer 832 that obtains control signals from the computer system 560 through RS-232 port 668.

Referring now to FIGS. 8A, B, and C, in a presently preferred embodiment, scanner means such as the scanner 550 is capable of moving a transceiver 530 vertically at a distance and at a rate that allows appropriately rapid scanning of the target. The scanner 550 includes a support means such as base 810 and upper frame 811; support beams 820; a motor drive system such as servomotor 830 and associated controls (see FIG. 7), a belt drive system such as belt 840, belt attachment 841, and support pulley 843; and guide 850 for slidable attachment to support beams 820. The scanner 550 is preferably constructed with panels 870 of metal or plastic to provide soundproofing and physical protection during scanner operation. The front of the scanner 550 is preferably covered with a window panel 880 fabricated from special low loss millimeter wave window material such as Rexolite (TM). Other materials that can be used include low loss tangent materials such as those that are usable in radomes (e.g. nylon, lucite, and the like). In addition to having low loss the materials should also be rigid. The window panel 880 should preferably not be so thick so as to substantially reduce sensitivity. At frequencies of about 110 GHz and below it should be no more than about one wavelength thick. While FIGS. 8B-C depict four beams 820 on which the transceiver 530 is slidably attached it is presently preferred to use two beams with the beams between positions 821 at the center of the sides of the transceiver 530, see FIG. 8C. This reduces the chances of binding during the mechanical scan. Limit switches 855 provide control for stopping the array assembly.

The scanner 550 can be operated in three modes of operation:

1. Automatic Mode: When a scan command is sent from the computer system 560 to the logic board 710, and motor indexer 832 the transceiver 530 will scan a predetermined test aperture, stop, and wait for another command. When a second scan command is sent, the transceiver 530 will be scanned to the other end of the predetermined aperture and wait for another command. This routine can be repeated as long as scan commands are issued.

2. Calibration Mode: Calibration Procedure for Holographic Arrays

As is apparent to those skilled in the art, a calibration procedure to correct for offsets and phase/amplitude variations in each holographic array channel is necessary for array normalization. This calibration process forces the holographic array to appear like a single element holographic system. Without this calibration processing, holographic imaging with array technology would not be possible. When a calibration command is sent to the motor indexer 832, the calibration procedure is performed in two steps. The first step is to correct for offsets, which step is performed by electronically scanning each antenna 1001 channel without a high reflective object in front of the transceiver 530 and store the offset values in the computer system 560. The stored offset values are used to force the array element offsets to the same value by appropriate calculations. The second calibration procedure is performed with a flat metal plate 890 that is perpendicular to the antenna array 618 on the transceiver 530, see FIG. 8B-C. Each of the 128 channels has a different phase and amplitude associated with it before calibration. The flat metal plate 890 provides a standard reference in which the phase and amplitude of each channel can be calibrated. This second calibration can be performed in the computer in a similar fashion as the first.

3. Manual Mode: The transceiver 530 can be positioned anywhere in the aperture using a manual controller. The manual controller may be part of the motor indexer 832.

The drive system is controlled by motor indexer 832 that is interfaced to the computer by a standard interface such as an RS-232. An example is stepper or servomotors controlled by a Parker Compumotor C3000 indexer. Scan speed should be appropriate to the target to be examined but can vary from about one to several seconds for a mechanical scanner to milliseconds for a totally electronic scanner for a seven foot scan aperture. An aperture scan for evaluation of human subjects at a transport facility, for example, must be fast enough so that movement of the individual does not interfere with the scanned image. While this can be accomplished with a fully electronic scanner, in the case of a mechanical scanner, depending on the speed of the scan moving objects or living subjects will ordinarily need to remain still for the duration of the scan. It is understood that in the preferred embodiment, as the transceiver 530 is electrically scanned across its width it is simultaneously scanned mechanically in a vertical direction. To provide good images it is preferred that one horizontal scan of both the upper and lower antenna arrays be complete before the antenna array assembly has moved one-tenth wavelength vertically; otherwise, the phase differences across the array may cause image degradation.

In the presently preferred embodiment the antenna array 618 uses waveguide (WR-28) for the KA-band, 26.5-40 GHz, arranged so the waveguide ends form two 64-element arrays at the antenna end with the orientation and spacing shown in FIG. 9. Waveguide up to and including the W-band can be used. FIG. 9 shows the arrangement of upper and lower antenna array 903,904 on the front of the antenna array 618. Waveguide spacing dimensions are given for 35 GHz. These dimensions can be varied within the limits of frequency and desired resolution of the obtained image. To obtain the best possible resolution of the final image, the waveguides need to be as close together as possible. In addition to using closer antenna spacing, resolution of the image can also be increased by operating at higher frequencies. Higher frequencies than the W-band are contemplated in the invention and would of course provide even greater resolution. For example, to obtain the tightest possible grouping at 35 GHz, without physical interference of the waveguides, the vertical spacing H is about 1 ½ wavelengths while the horizontal spacing A is about 1 ⅛ wavelengths. The upper antenna array 903 and lower antenna array 904 are offset by distance B which is preferably 1/2A. Polygonal antenna 1001 fit into the waveguides 901. Individual channel numbers (1-128) are noted next to the upper and lower waveguides 901. FIG. 10 shows a side view, A, and top view, B, of a typical antenna 1001 useful at 35 GHz, while FIG. 11 shows the general arrangement of the antenna array 618 on the front of the transceiver 530.

The maximum number of antenna elements is determined by the frequency of the array and the array width or area to be covered. The higher the frequency the more elements may be incorporated since the major limitation on increasing the number of elements is basically the size of the waveguide. In FIGS. 9 and 10 this limitation is readily apparent by the waveguide spacing. Here it is seen that the individual antenna are sized to fit directly in the waveguide and thus the waveguide size is the limitation on the array. The higher the number of elements for a given area the greater will be the resolving power of the device. This is of course limited by the wavelength of the millimeter waves used. In order to obtain higher frequency operation, waveguide and/or antenna fabricated by techniques such as those for microstrip patch antenna that allows closer spacings are contemplated. For example, as a rule of thumb, the resolving power of a detection system is about one wavelength although theoretically one would expect it to be one-half the wavelength. Thus at 26.5 GHz the resolution is limited to about 1.13 cm (theoretical is 0.57 cm), while at 110 GHz the resolution is limited to about 0.27 cm (theoretical is 0.14 cm).

The beam width of the polyrod antenna 1001 determines the lateral resolution (F#) of the linear holographic surveillance system 500. To increase lateral resolution, the beam width of the polyrod antenna 1001 must be increased. By increasing the antenna beam width, the gain of the antenna is decreased; however, this decreases sensitivity to reflected target signals. In addition, increasing the antenna beam width can create mutual coupling problems between antennas in linear and two dimensional holographic arrays. Mutual coupling problems can degrade the image quality. Typically, the polyrod antenna beam width is chosen so that the highest spatial frequency that can be captured in a holographic detection system is one wavelength. To meet the Nyquist sampling criteria, the aperture must be sampled at least every one-half wavelength. In the preferred method discussed above the sampling in the horizontal dimension is fixed by the array spacing between elements. (See FIG. 9, where space A 910 between channels 1 and 2 is the array spacing). This spacing in the present system is two-thirds of a wavelength and therefore does not meet the Nyquist sampling criteria. However, this spacing was chosen as a compromise between the antenna gain and beam width, possible aliasing in the imaging due to under sampling of a high spacial frequency target, and mutual coupling problems between antennas. The spacing 910 may be varied between about ½ to about ¾ wavelength with the optimum dimension being easily chosen for a particular frequency and application by those skilled in the art.

As will be appreciated by those skilled in the art, the antenna array could also be arranged so as to be mechanically scanned horizontally, circularly, or to be arranged as a two dimensional array and have sufficient antenna placed so as not to require mechanical scanning. If desired, two or more antenna arrays 550 could be arranged so as to scan any of the four vertical or two horizontal geometric planes of a subject, i.e. sides, top, and/or bottom. FIG. 5 shows an additional transceiver and scanner 555 to accomplish this. One or more additional scanners 555 are useful since the millimeter waves do not penetrate the human body like x-rays and therefore only one surface of the body is revealed during a scan.

FIG. 12 shows the general timing sequence for an outgoing signal for the first four individual channels of the antenna array 618. Each channel should ordinarily be "on" about 1 to 1.5 usec at a frequency of 35 GHz at the repetition rate provided by the clock. The remaining 124 channels are sequenced similarly, with channels 5 to 64 addressed first, then channels 65 to 128.

While systems operating at frequencies of 35 GHz and 90 GHz have been described above the useful frequency range for detectors of the type described herein may range from 26.5 GHz to 110 GHz and above and is most preferably from 35 to 95 GHz etc.

While the forms of the invention herein disclosed constitute presently preferred embodiments, many others are possible. It is not intended herein to mention all of the possible equivalent forms or ramifications of the invention. It is to be understood that the terms used herein are merely descriptive, rather than limiting, and that various changes may be made without departing from the spirit or scope of the invention.

REFERENCES

Although the below listed references discuss acoustical holography, the same principles as disclosed therein are applicable to the understanding of the present invention.

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5. Goodman, J.W. 1968. Introduction to Fourier Optics, pp. 129-131, McGraw Hill, New York.

6. Hildebrand, B.P. and K. Haines. 1969. "Holography by Scanning," Journal of the Optical Society of America, 59:1-6.

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CLAIMS

We Claim:

1. A holographic surveillance apparatus having at least one antenna element, means for illuminating a target with high frequency millimeter wave radiation at frequencies from about 26.5 GHz to about 110 GHz, and means for obtaining and numerically processing both amplitude and phase data from the high frequency millimeter wave radiation for constructing holograms, characterized in that:

(a) said high frequency millimeter wave radiation is combined with,

(b) said antenna element placed at positions closely spaced apart from about 0.25 to about 1.75 wavelength of said high frequency millimeter wave radiation, and said antenna element is used for both transmitting said high frequency millimeter wave radiation to the target and receiving high frequency millimeter wave radiation reflected from the target,

(c) thereby producing a holographic image of a resolution of from about 0.14 cm to about 1.13 cm resulting in a recognizable holographic image of said target.

2. The apparatus as recited in claim 1, wherein said antenna element is a polyrod antenna element.

3. The apparatus as recited in claim 1, wherein a plurality of antenna elements are arranged in a first linear array, said first array moved by a mechanical means during transmission and receipt of said high frequency millimeter wave radiation.

4. The apparatus as recited in claim 3, wherein the first linear array is an upper array, and additional antenna elements are arranged in a second lower

horizontal linear array, wherein the two arrays are offset by half the spacing between antenna elements, thereby enhancing vertical resolution as the upper and lower arrays are moved vertically.

5. The apparatus as recited in claim 1, wherein a plurality of antenna elements are spaced in a stationary, multi-dimensional array.

6. The apparatus as recited in claim 5, wherein a multi-dimensional array is a planar two-dimensional array.

7. A holographic surveillance apparatus having at least one antenna element, means for illuminating a target with high frequency millimeter wave radiation at frequencies from about 26.5 GHz to about 110 GHz, and means for obtaining and numerically processing both amplitude and phase data from the high frequency millimeter wave radiation for constructing holograms characterized in that:

(a) said high frequency millimeter wave radiation is combined with,

(b) said antenna element placed at positions closely spaced apart in said array from about 0.25 to about 1.75 wavelength of said high frequency millimeter wave radiation,

(c) said antenna element used for both transmitting said high frequency millimeter wave radiation to the target and receiving high frequency millimeter wave radiation reflected from the target, and

(d) electronically controlled scanner for moving the antenna element rapidly across an aperture, from about several milliseconds to about several seconds, together with electronic data processing for providing a holographic image of the target in a short amount of time practical for personnel surveillance.

8. An apparatus as recited in claim 7, wherein said antenna element is a polyrod antenna element.

9. An apparatus as recited in claim 7, wherein a holographic image of a resolution of from about 0.14 cm to about 1.13 cm is produced resulting in a recognizable holographic image of said target.

10. A method for holographic surveillance by illuminating a target with high frequency millimeter wave radiation at frequencies from about 26.5 GHz to about 110 GHz, and collecting high frequency millimeter wave radiation reflected from the target with at least one antenna element, and constructing a holographic image of the target by obtaining and numerically processing both amplitude and phase data from the reflected high frequency millimeter wave radiation, characterized in that:

(a) illuminating a target with high frequency millimeter wave radiation is combined with,

(b) placing the antenna element in a plurality of positions spaced from about 0.25 to about 1.75 wavelength of said high frequency millimeter wave radiation, and

(c) using said antenna element sequentially for both transmitting said high frequency millimeter wave radiation to the target and receiving high frequency millimeter wave radiation reflected from the target.

11. A method as recited in claim 10, wherein placing the antenna element in a plurality of positions, comprises:

scanning a target rapidly with high frequency millimeter wave radiation transmitted from the antenna element, from about several milliseconds to about several seconds.

12. A method as recited in claim 11, further comprising:

electronically processing data collected from the scanning for providing a holographic image of said target, said image having a resolution of from about 0.14 cm to about 1.13 cm resulting in a recognizable holographic image of the target in a short amount of time practical for personnel surveillance.

13. The method as recited in claim 10, wherein said antenna element is a polyrod antenna element.

14. The method as recited in claim 11, wherein a plurality of antenna elements are arranged in a first linear array, said first array moved by a mechanical means during transmission and receipt of said high frequency millimeter wave radiation.

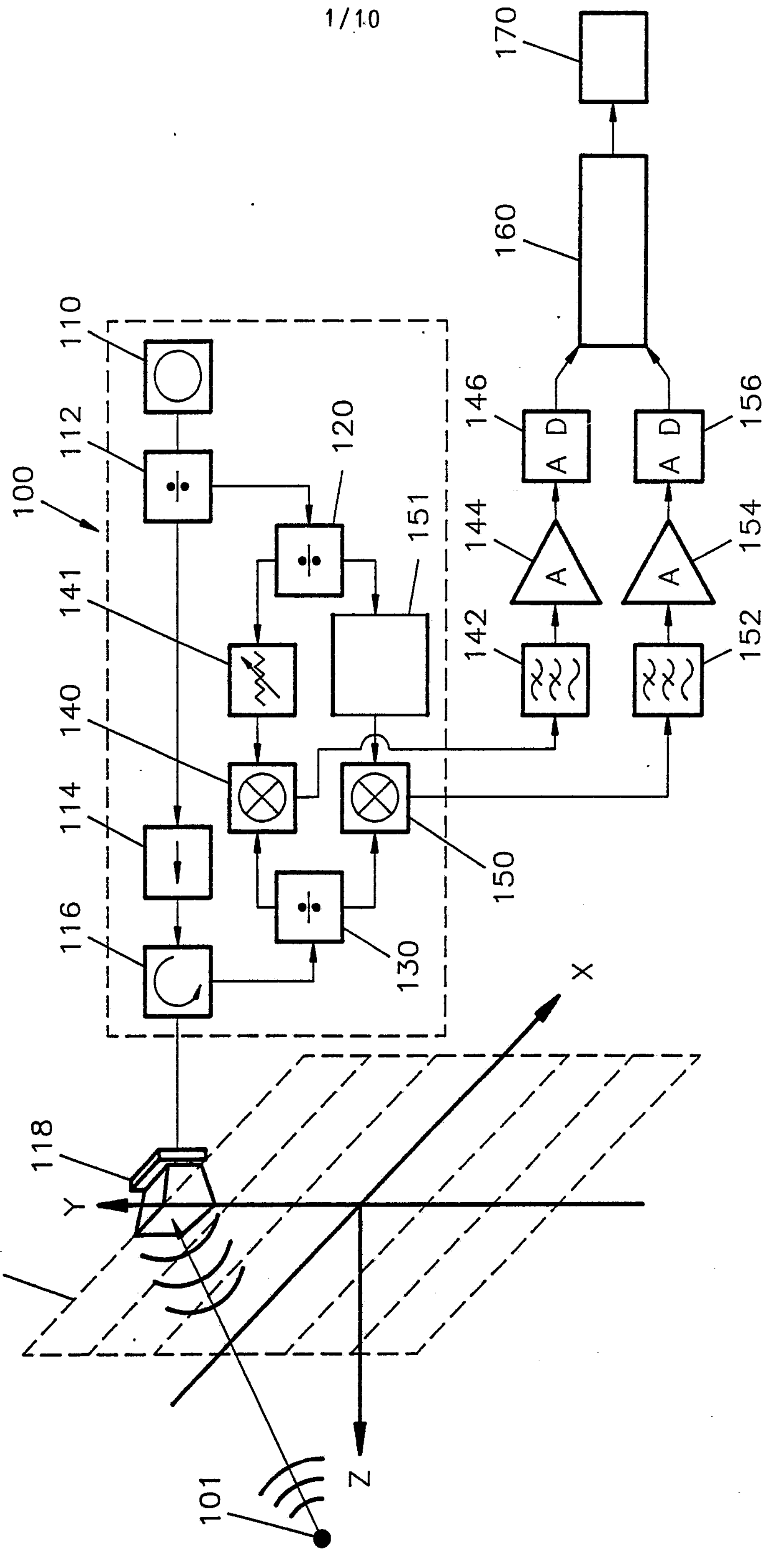
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FIGURE 1

FIGURE 2 (a)

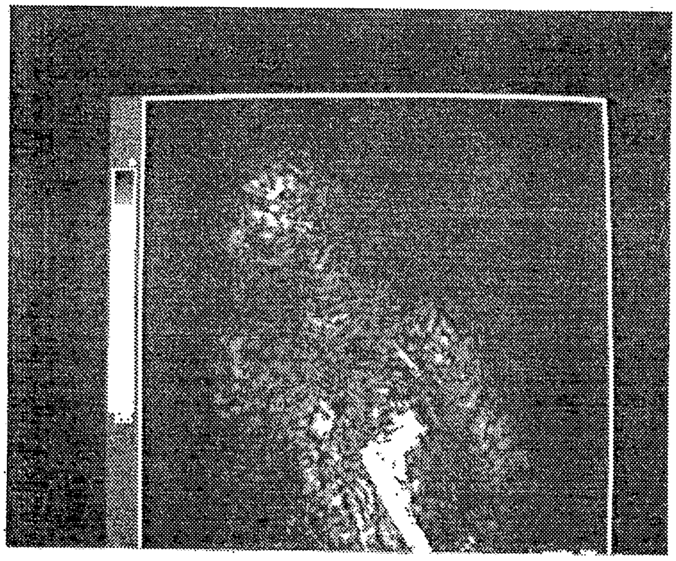


FIGURE 2 (b)

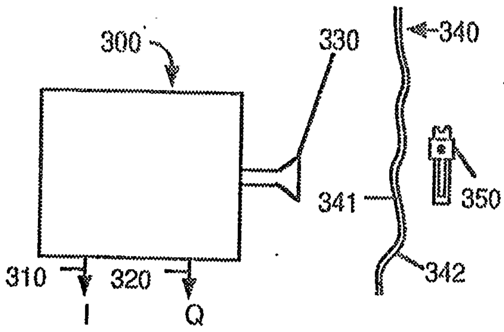


FIGURE 3 (a)

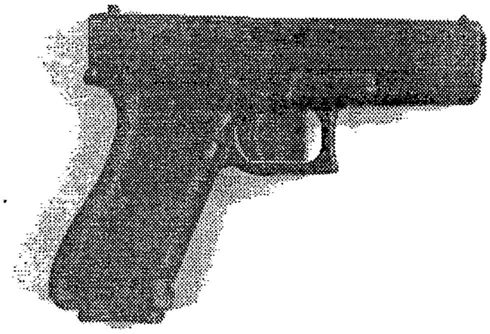


FIGURE 3 (b)

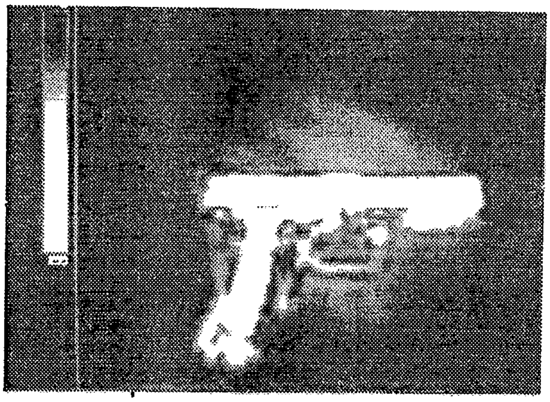


FIGURE 3 (c)

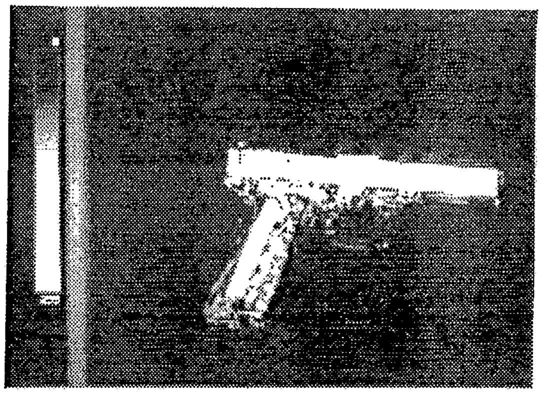


FIGURE 3 (d)

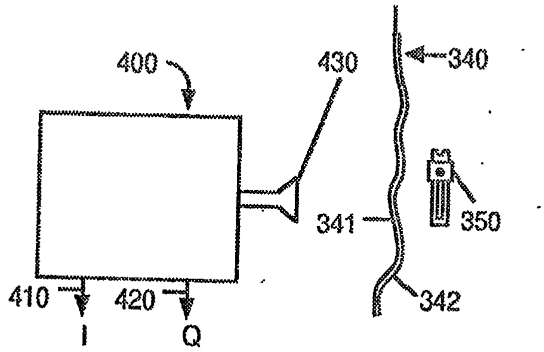


FIGURE 4 (a)

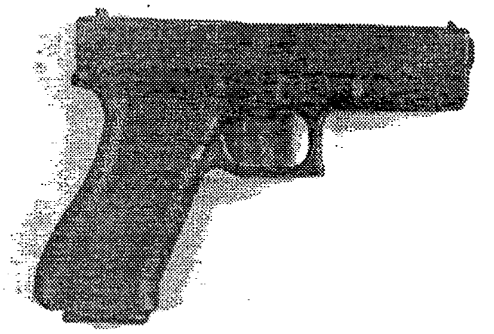


FIGURE 4 (b)

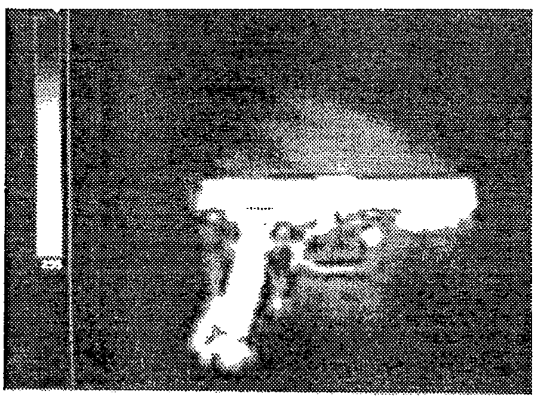


FIGURE 4 (c)

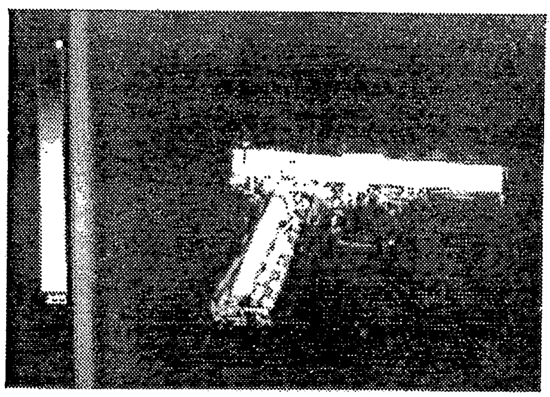


FIGURE 4 (d)

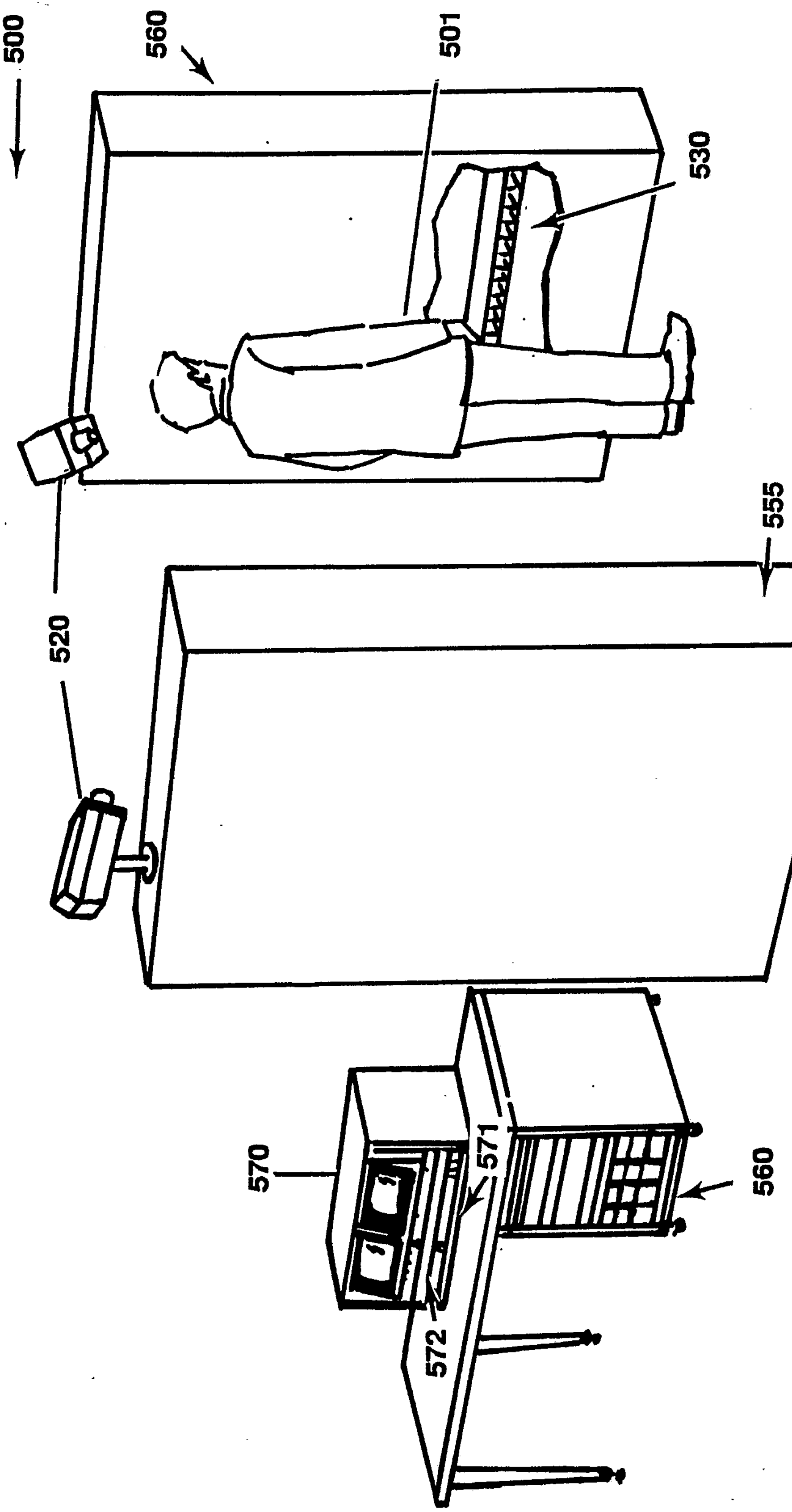
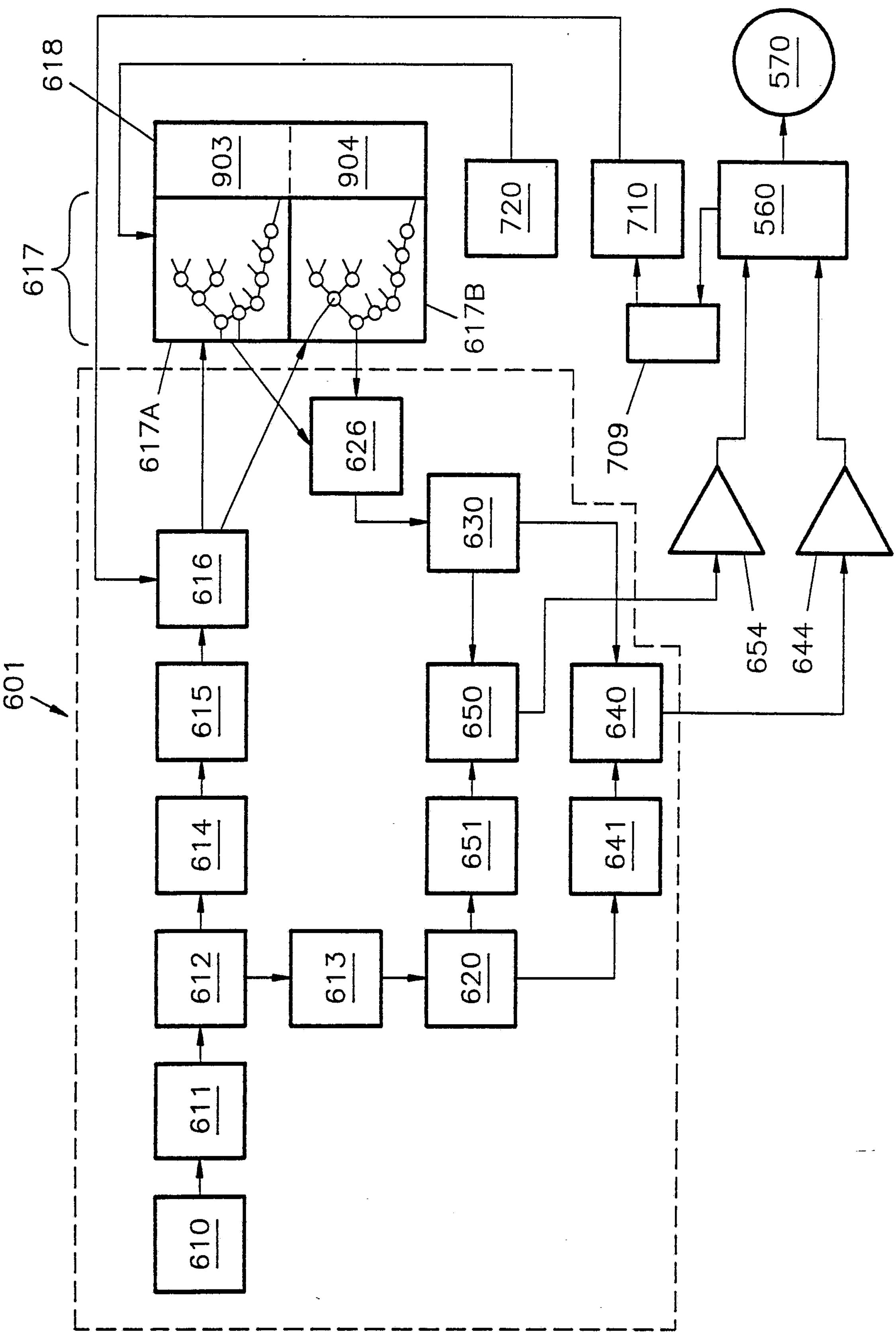


FIGURE 5


618
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904
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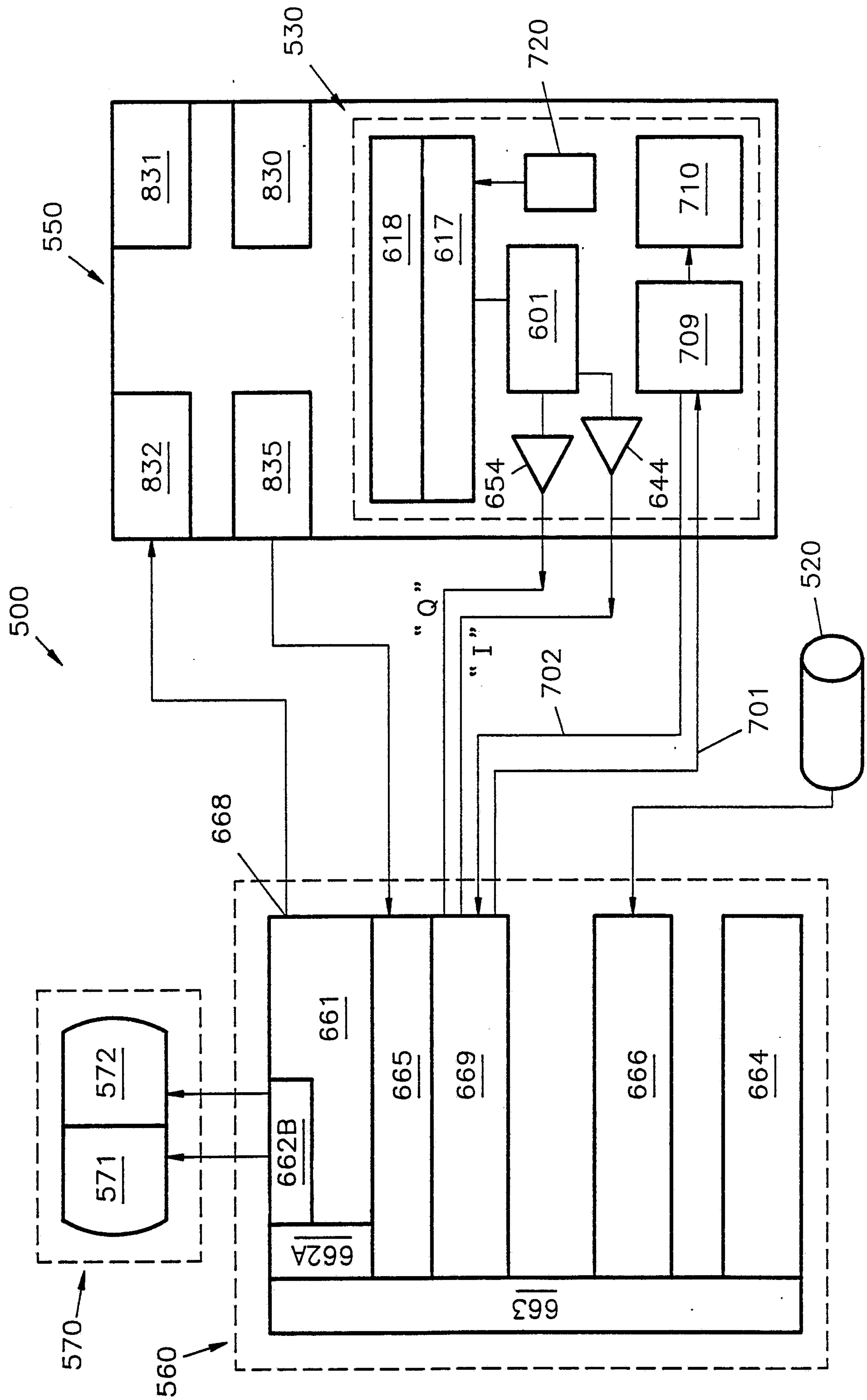
FIGURE 6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"Q"
"I"
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662B
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FIGURE 7

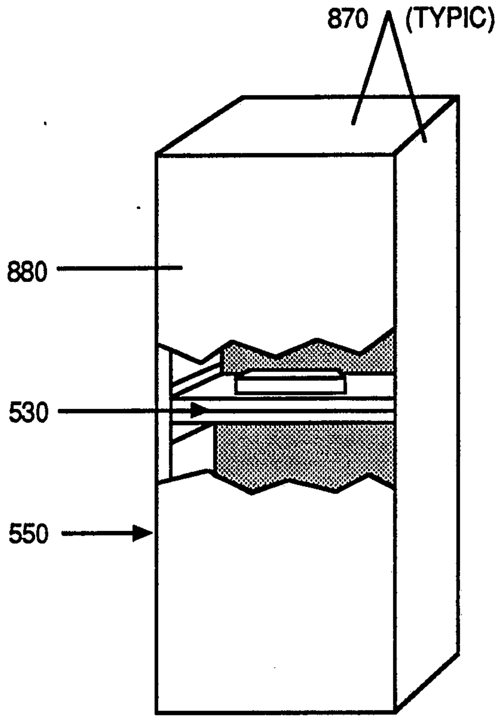


FIGURE 8 (a)

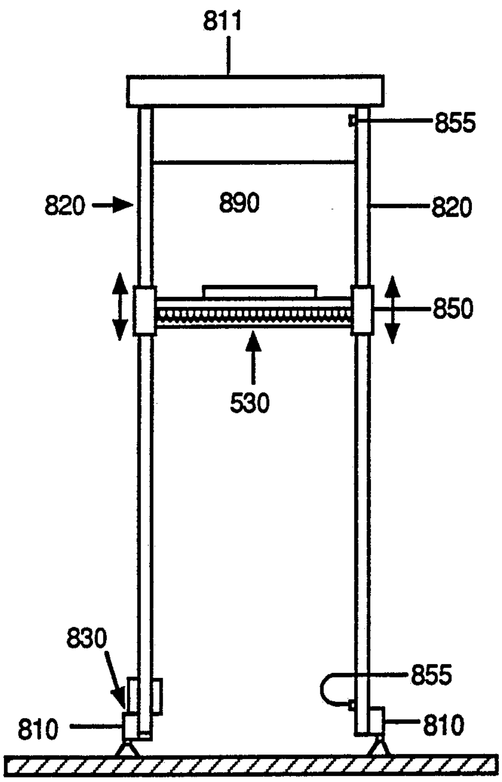


FIGURE 8 (b)

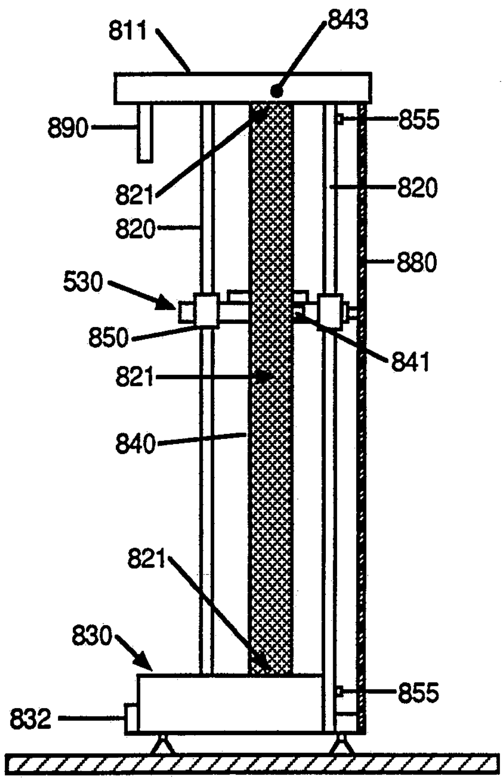


FIGURE 8 (c)

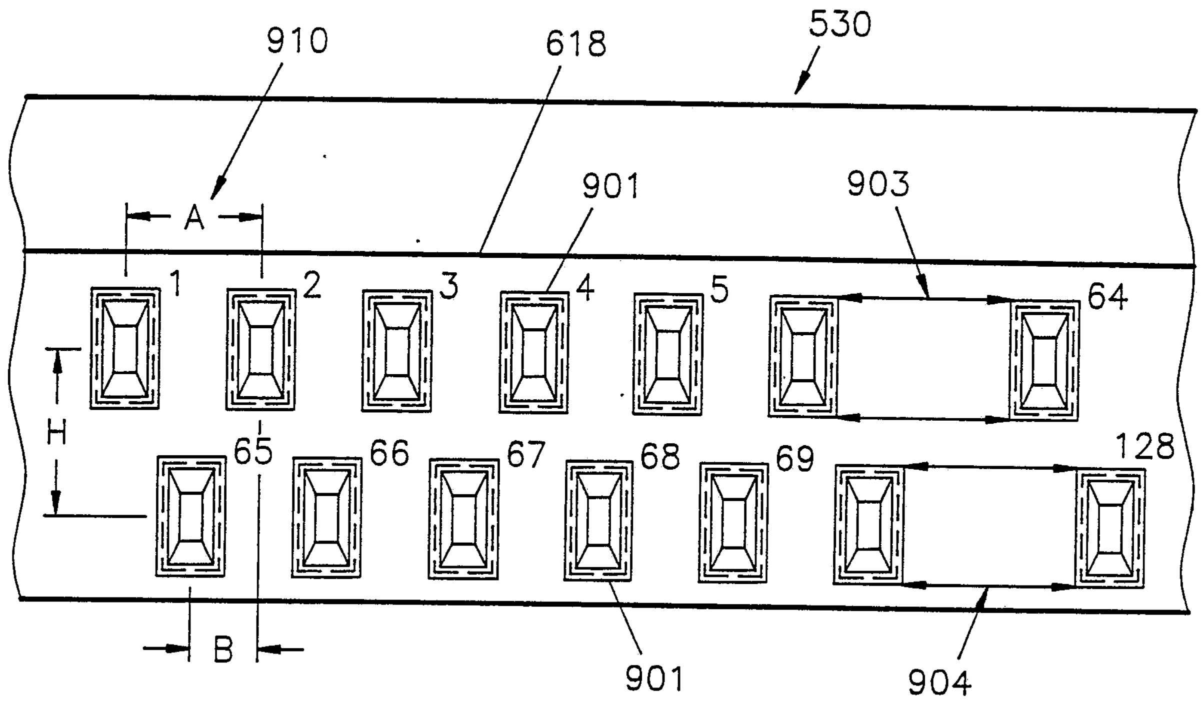


FIGURE 9

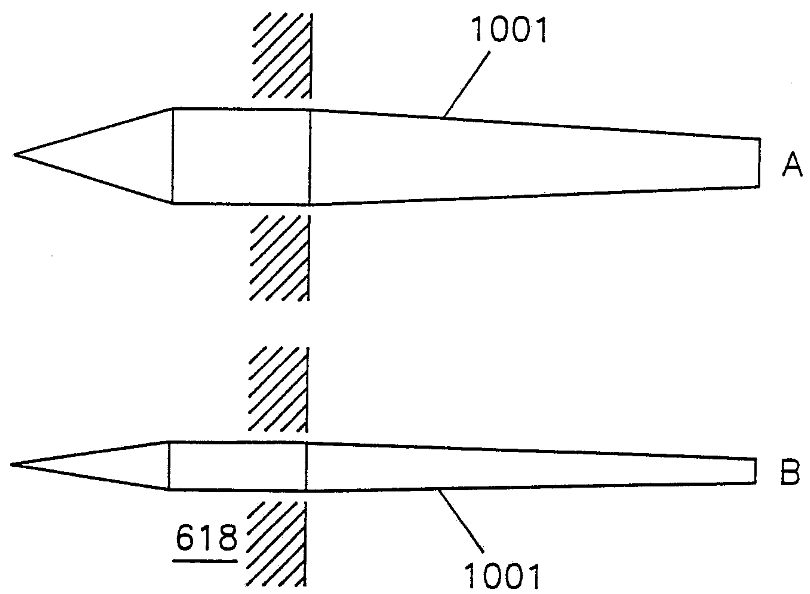


FIGURE 10

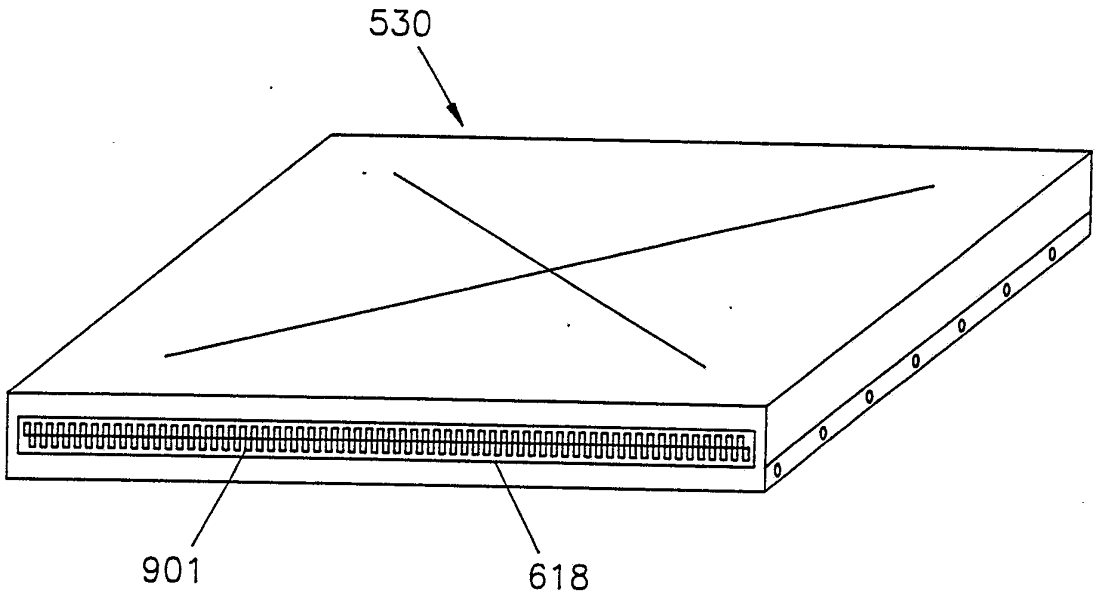
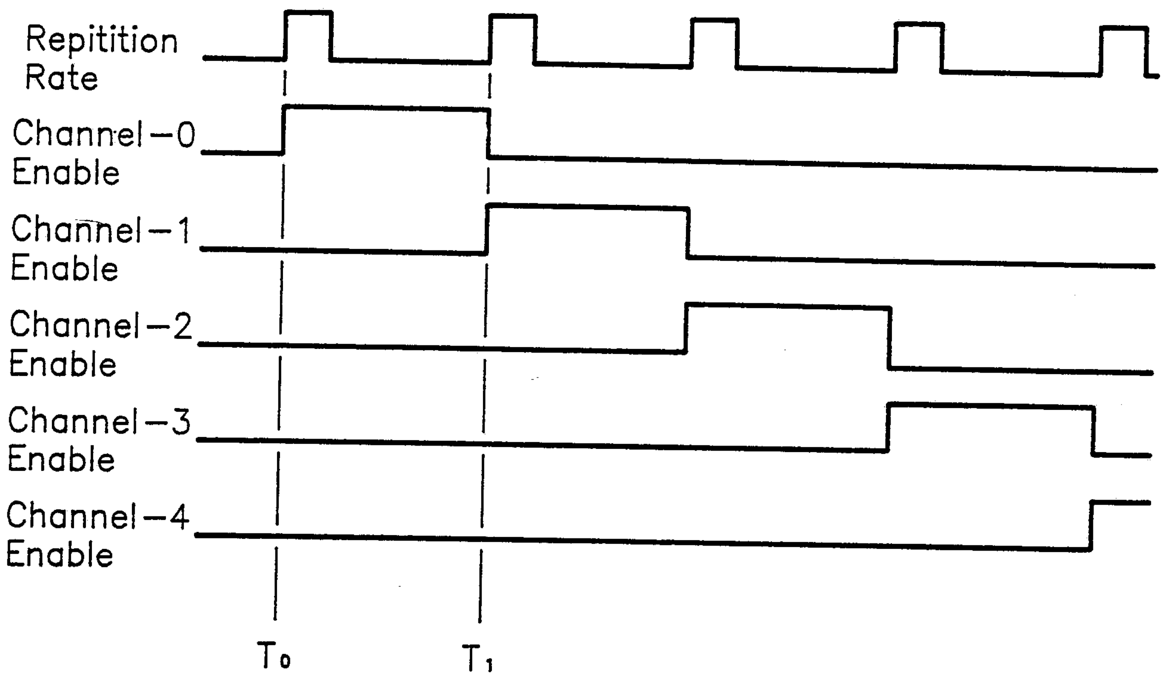


FIGURE 11



T_0 to T_1 = 1.5 μsec

FIGURE 12

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 92/04476

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 G01S13/89; G03H5/00; G01N22/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	G01S ; H01Q ; G03H

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	GB,A,2 034 554 (EMI) 4 June 1980 see the whole document ---	1-14
X	IGARSS 87 vol. 1, 18 May 1987, ANN ARBOR MI US pages 571 - 576 Y. AOKI ET AL. 'diagnosis of under-snow radar images by three-dimensional displaying technique in holographic imaging radar' see paragraph 2 -paragraph 5; figures 3,5 ---	1,7,10
A	WO,A,8 202 781 (ALASAARELA) 19 August 1982 see page 2, line 5 - line 16 see page 6, line 21 - page 7, line 31 ---	1,7,10

-/--

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

1

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 SEPTEMBER 1992	29. 09. 92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	AUGARDE E.P.G.T.

International Application No PCT/US 92/04476

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	INTERNATIONAL JOURNAL OF INFRARED AND MILLIMETER WAVES vol. 11, no. 2, February 1990, NEW YORK US pages 101 - 110 R. GLÖCKLER 'Phased array for millimeter wave frequencies' see paragraph 2; figure 2 ---	2,13
P,A	US,A,5 081 456 (MICHIGUCHI ET AL.) 14 January 1992 see column 4, line 60 - column 5, line 33; figure 6	3-4,14
A	& JP,A,63 255 683 (HITACHI) -----	

Form PCT/ISA/210 (extra sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 9204476 SA 61788

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 17/09/92
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
GB-A-2034554	04-06-80	None		
WO-A-8202781	19-08-82	EP-A,B	0083584	20-07-83
		JP-T-	58500495	31-03-83
US-A-5081456	14-01-92	JP-A-	63255683	21-10-88

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82