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(54) **Concealed antenna**

(57) The present invention relates to a slot antenna concealed in a vehicle for communicating the vehicle location to a base tracking station. There is a risk that criminals may evade the security measures by finding and removing the antenna. Therefore the slot antenna 9 is concealed inside a lamp unit enclosure 16. In the main embodiment the slot antenna 9 is behind an optical reflector 14 of the lamp unit and the optical reflector comprises portions of electrically conducted material which are electrically isolated from each other so as to limit

conduction of electric currents in the optical reflector. This may be by way of a metallic paint with an electrically insulating binding medium or a plurality of separate conducting panels mounted on an insulating substrate. The use of a tuned resonator 17 to reflect the back-directed signal from the slot antenna 9 is also disclosed. Another embodiment relates to a plurality of LEDs 21 aligned with the slot 19 of a slot antenna 20. As the slot antenna is positioned in the lamp unit, it cannot be screened without conspicuously covering the lamp and making night driving impossible.

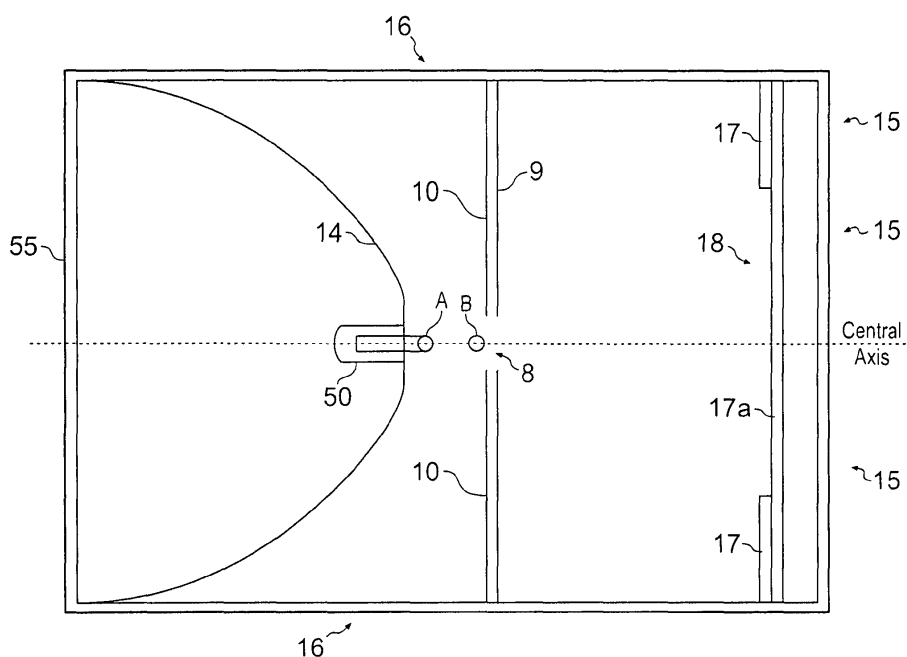


Fig. 3

Description

[0001] The present invention relates to an antenna for use in a vehicle radio communication system for transmission of position or other data to and/or from a vehicle, preferably but not necessarily by radio waves of the order of 900 MHz frequency or higher. In this specification the term "vehicle" is used to mean a motor vehicle having wheels for use on a public road or, alternatively building equipment fitted with wheels and/or caterpillar tracks.

[0002] At present, vehicle mobile data communication systems tend to use a quarter wave whip antenna mounted above a ground plane which is provided by a surface of the body of the vehicle concerned. This arrangement is vulnerable to damage, accidental or deliberate, and to a large extent negates the value of such a radio communication system as a security aid, because a person seeking to steal a vehicle merely has to disable the antenna in order to sever the communication between the vehicle and the tracking base station. Such disablement of the antenna may be achieved by physically breaking it off, by bending or deforming in such a way that it no longer functions, or by screening the antenna electrically.

[0003] The use of a concealed antenna is one possible solution to the problem outlined above. Our application GB2352334 disclosed a slot antenna suitable for concealing within a vehicle. However this approach has serious limitations. Criminals would soon discover the likely location of the concealed antenna and, in the case of a slot antenna, metallic foil could be placed over the area of the antenna in order to disable it.

[0004] Our application GB2341504 describes a vehicle tracking system having a plurality of radio communication antennas mounted within the vehicle, and arranged so that if one antenna is disabled the other or remainder are capable of continuing to function. However, this still has the problem that the antennas can be located and disabled.

[0005] Accordingly the inventor has experimented with concealing an antenna in one of the lamp units of a vehicle. In fact it is possible to have more than one antenna, each antenna being in a different lamp unit. Thus, the potential thief has to screen all possible antenna enclosures with conducting foil and consequently for a conventional vehicle five screens would be necessary - for the headlamps, rear lamps and tail lamp. Screening of this type would render the vehicle conspicuous during daylight and make driving impossible at night.

[0006] However, concealing an antenna in the lamp unit of a vehicle is not a simple matter. It is necessary to ensure that the antenna does not obstruct the light source and also that any metal in the lamp unit does not prevent effective reception and transmission of the radio signal. It is also desirable to design the lamp unit so that it is compact and does not differ in appearance from a

conventional lamp unit not having an antenna.

[0007] Accordingly, at its most general, one aspect of the present invention provides a lamp unit for a vehicle comprising an antenna for transmitting and/or receiving radio waves and an optical reflector for reflecting light, wherein the optical reflector comprises portions of electrically conductive material which are electrically isolated from each other so as to limit conduction of electric currents in the optical reflector.

[0008] Thus, a first aspect of the present invention may provide a lamp unit for a vehicle comprising a curved optical reflector having a convex side and a concave side for reflecting light out of the lamp unit, a light source positioned adjacent to the concave side of the reflector, and a slot antenna positioned opposite the convex side of the optical reflector for transmitting and/or receiving radio waves, the concave side of the optical reflector comprising portions of electrically conductive material for reflecting light out of the lamp unit, said portions of electrically conductive material being electrically isolated from each other so as to limit induction of electrical currents in the reflector, the optical reflector further comprising an electrically non-conductive material for supporting or holding together said portions of electrically conductive material.

[0009] Conventional optical reflectors in modern headlamp systems comprise an insulating body coated with a metallic reflecting film. If this conventional type of optical reflector was used in the present invention, then a signal from the antenna would cause currents to be induced in the metal coating of the optical reflector. However, in the above configuration this problem can be avoided by isolating the portions of electrically conductive material in the reflector from each other and making said portions small enough that the induced currents are minimized. In particular circulating currents and current perpendicular to the longitudinal length of the slot of the slot antenna are substantially reduced or prevented. Attenuation of the radiated signal can thus be reduced and may be kept to a negligible level.

[0010] Furthermore, because the optical reflector does not significantly attenuate the radiated signal, it is possible to place the slot antenna behind the light source (if significant attenuation occurred it would have to be placed in front of the light source). When it is placed behind the light source, the antenna can be concealed from view and does not interfere with projection of light out of the lamp unit.

[0011] Thus the radio waves should be able to pass through the optical reflector without significant attenuation and certainly with reduced attenuation compared to a case if a conventional optical reflector was used. If the system uses a 900 MHz system then the individual portions of electrically conductive material are preferably no larger than 150 mm² (e.g. 10x15 mm panel) otherwise some attenuation of the transmitted signal will occur. Of course the portions of electrically conducted material can be much smaller. At higher frequencies the

portions of electrically conductive material will have to be correspondingly smaller.

[0012] Preferably said electrically non-conductive material takes the form of a substrate on which the portions of electrically conductive material are mounted. Any suitable electrically non-conductive material may be used; e.g. a plastics material, preferably a plastics material with very low power loss at the antenna frequency.

[0013] The electrically conductive material will usually be a metal.

[0014] The portions of electrically conductive material may be provided by panels of electrically conductive material, which are electrically isolated from each other. Usually the panels will be mounted on an insulating substrate of electrically non-conductive material. The panels perform the function of reflecting light from the light source so as to project the light out of the lamp unit. The substrate supports the panels.

[0015] The panels may be arranged in a matrix, e.g. a plurality of square or rectangular panels arranged in a grid. Alternatively the matrix panels may be triangular, pentagonal, hexagonal or other shapes. The point of arranging the panels in so called "matrix" is that as the concave surface of the optical reflective is then divided into a plurality of segments both lengthways and width ways, it is not possible for large currents to circulate in the optical reflector. If longer panels extending the whole width or the whole length of the optical reflector where used then there would be more risk of circulating currents taking energy from the radio signals when they pass through the optical reflector.

[0016] In general the panels should be configured in a geometrical arrangement adapted to prevent the circulation of currents within the optical reflector. For example by way of a matrix or by alignment of strips parallel to the longitudinal extent of the antenna slot so as to keep the strips perpendicular to the E vector as described above. The area and orientation of the panels is such that attenuation is minimized. The gaps between the panels (which are electrically isolated from each other) can be kept fine enough that the optical performance of the reflector is substantially unaffected.

[0017] Although the gaps between the panels can be kept fine, it may still be possible for an interested observer to spot the dividing lines on the concave surface of the optical reflector. Therefore it is preferred that a front window of the lamp unit (for allowing light to exit the unit) has a pattern which obscures the dividing lines between the optical reflector's panels.

[0018] One possibility is a window or lens having a series of ridges or prisms (e.g. a fresnel lens). Such an arrangement generally deviates the light passing through it so that it is not possible to inspect the surface of the optical detector. The ridges or prisms usually also focus or concentrate the light in a particular direction.

[0019] It would also be possible for the panels to be a plurality of thin elongate strips of conductive material,

each strip extending all the way across the reflector; this arrangement is effective provided the E vector of the radio waves is perpendicular to the longitudinal direction of the strips. This is not always the case in the immediate vicinity of the antenna however and the concave shape of the reflector means that the E vector will impact upon it at various angles. Therefore this configuration is not as effective as the matrix of panels described above.

[0020] The panels may each be separately mounted onto the substrate, or may be formed by scoring of an optically reflective conductive layer that has been mounted on the non-conductive substrate. As long as the cuts are deep enough, extending down to the non-conductive substrate, the separate panels of conductive material formed by this latter method will be electrically isolated from each other. A grid of panels can be formed by making vertical and horizontal scores across the conductive layer. Elongate strip panels can be formed by scoring the conductive layer only in one direction - e.g. horizontal.

[0021] As an alternative to electrically conductive panels, the reflector may comprise a layer of metallic paint containing metallic particles in an electrically non-conductive binding medium (e.g. a solvent for the metallic particles). The metallic particles are then electrically isolated from each other by the binding medium when the paint is dry. Typically the metallic paint will be coated onto an electrically non-conductive substrate forming part of the optical reflector.

[0022] Preferably the lamp unit comprises an enclosure enclosing the light source, reflector and slot antenna. The enclosure will have a window at one end facing the concave side of the optical reflector, so that light reflected by the optical reflector can pass out of the window.

[0023] Preferably the other walls of the enclosure are coated with a conductive layer. This conductive layer then acts as a screen that channels the radiated radio signal in the desired direction out of the lamp unit when the antenna is transmitting and reduces outside interference when the antenna is receiving.

[0024] Preferably the outer walls of the enclosure are formed of a non-conductive material and the outside surfaces of these walls are coated with a conductive material. In this way the screen provided by the conductive material on the outer surfaces is conveniently electrically insulated from the slot antenna which can then abut against the inner surfaces of said walls.

[0025] Alternatively the walls of the enclosure may be formed of a non-conductive material, but not coated with a conductive material, i.e. it can be unscreened. This allows radiation to pass through the walls of the enclosure. While this is undesirable in vehicles which have metal body panels, an increasing number of vehicles are now made partially of plastics. Where the vehicle panels (e.g. wings or bumpers) are made of a metal material, then radiation passing through them is mostly absorbed. In that case the only viable path for entry and exit of the

radio signal is through the window of the lamp unit. However, where the vehicle body panels are made of a plastics material, then it is possible for radiation to pass through these panels and it can be advantageous to use an unscreened headlamp enclosure to maximize the transmission and reception of radiation.

Preferably any conductors in the lamp unit, especially conducting cables (e.g. the sheath of a coaxial cable connected to the antenna, or a supply cable connected to the light source) lie substantially entirely in the plane in which the longitudinal axis of the slot of the slot antenna lies or in a plane parallel thereto. This minimizes or prevents reduction of power by induction of currents in the components of the lamp unit.

[0026] Preferably any cables for supplying the light source are provided with chokes such as helically wound coils. This helps to reduce signal loss due to energy transmission out of the enclosure via the light source supply cables.

Preferably the slot antenna comprises an electrically conductive panel having an elongate slot in it, the effective length of the slot being approximately an integral sub-multiple of the wavelength of the radiation with which the antenna is to be used. The slot may be a void, or may alternatively be filled with an electrically non-conductive material; in either case it is important that it is non-conductive.

[0027] The slot antenna may conveniently take the form of a substrate panel of non-electrically conductive material and a layer of electrically conductive material coated or mounted on to one face of the substrate, an elongate slot being formed in the conductive layer.

[0028] The non-electrically conductive material of the substrate panel should have a low power factor (internal power loss) at the antenna frequency. It may have a slot cut away at a location corresponding to the elongate slot of the conductive layer. If the substrate panel has a slot in this manner then the antenna is likely to be more effective and have sharper tuning than the case would be if it does not. Whether or not that substrate panel has a slot corresponding to the slot of the electrically conductive layer can be chosen depending on the frequency range of the transmissions which are to be used.

Preferably the slot antenna has a coaxial feed cable the central conductor of which is connected to one longitudinal edge of the slot of the antenna and the screen of which is connected to the other longitudinal edge of the slot opposite the first connection.

[0029] Preferably the feed cable connection to the slot is made in such a way that the feed line is non-resonant at the operating frequency and is matched to the impedance of the antenna independently of the length of the feed cable.

[0030] Preferably the antenna has means for attaching its conducting panel to the structure of the vehicle (e.g. the lamp unit) in such a manner that vertical polarisation of the electric vector of the radiation is achieved when the longitudinal axis of the non-conducting region

(the slot) is substantially horizontal.

[0031] Preferably the slot of the substrate panel is in the form of a parallel-sided slot, a dumb bell slot, or a rectangular notch cut into the edge of the substrate panel.

[0032] Preferably the antenna's substrate panel is in the form of a folded rectangular slot.

[0033] The lamp unit may also comprise a radio wave reflector element located closely adjacent the side of the slot antenna which faces away from the convex side of the optical reflector. The radio wave reflector element then acts to reflect the signal radiated on that side of the slot antenna, thereby to augment the signal radiated in a desired direction (e.g. through the window of the lamp unit). The reflected signal may pass through the antenna slot and, in some cases, also around the edges of the antenna panel and the optical reflector assembly. The radio wave reflector element may be insulated from the antenna by insulating pillars, insulating walls of the lamp unit enclosure or other means.

[0034] The radio wave reflector element may take the form of a conductive panel and preferably has at least one dimension greater than the conductive panel of the slot antenna. If a solid conductive panel is used as the radio wave reflector element then it is best placed a distance of the order of one quarter of the wavelength of the signal radiated by the antenna away from the antenna. This ensures that a significant quantity of radiation is reflected. However, if instead of a solid panel a tuned resonator, e.g. a conductive panel with a slot in it, is used instead then it can be placed closer to the slot antenna and the lamp unit can be made more compact. This approach is discussed below under the second aspect of the present invention. Preferably the conductive panel is planar.

[0035] Preferably the lamp unit is part of a vehicle tracking system. Preferably the system includes means for determining the position of the vehicle from received radio waves (e.g. global positioning system signals which may be received by a GPS antenna mounted on the vehicle), means for producing vehicle position data signals based on the received radio waves and means (e.g. a slot antenna) for communicating said vehicle position data signals to a base tracking station.

[0036] Preferably the system comprises a plurality of antennas (each of which may be located in a different lamp unit) and the antennas are electrically balanced and matched such that in the event of one antenna being disabled the other antenna or the remainder of the antennas are capable of continuing to function.

[0037] In general it has been found to be convenient to use slot antennas in vehicle tracking systems. This is because slot antennas can easily be integrated into the existing framework of the vehicle, are easily concealed and can be cheap to manufacture. When a slot antenna is used it is desirable to have a radio wave reflecting element opposite one face of the slot antenna, so as to direct the radiation in the desired direction (and to

screen background radiation when in the receiving mode).

[0038] One possible solution is to use a conductive panel as the radio wave reflecting element. However, this has the disadvantage that such a panel needs to be positioned about one quarter wavelength of the frequency of the radio waves to be used away from the slot antenna if it is to function at its best. This can cause the antenna system to take a great deal of space. The amount of space used is an important consideration when the slot antenna is concealed in a lamp unit, but also in other situations when the slot antenna is positioned in another part of the vehicle. In general the smaller the antenna system is the easier it will be to conceal.

[0039] Therefore, the radio wave reflecting element in preferably a tuned resonator in the form of a conductive panel having an elongate slot. The tuned resonator may be tuned to approximately the resonant frequency of the slot antenna; in fact it may have the same physical dimensions and be made of the same material as the slot antenna, but will differ in that it is not connected to any conducting leads for transmitting/receiving a signal. When a tuned resonator is used as the radio wave reflecting element, it can be placed closer to the slot antenna. This is possible because the phase of the current induced in the tuned resonator compared to a solid conductive reflector panel may be altered by selecting or adjusting the tuning of the resonator appropriately. In general the resonant frequency of the tuned resonator will not differ from the signal frequency (or the resonant frequency of the slot antenna) by more than 20%. In this case the tuned resonator may be placed at a distance less than one quarter wavelength of the resonant frequency of the slot antenna behind the slot antenna. Preferably the slot antenna and the tuned resonator are parallel to each other. Preferably they are spaced apart by a distance such that, in use, a signal transmitted from the slot antenna interferes constructively at the lamp unit's window with radiation reflected back through or around the slot antenna by the tuned resonator.

A second aspect of the present invention provides a slot antenna system for use in a vehicle radio communication system, comprising an electrically conductive panel adapted to be carried by or to form part of the structure of the vehicle, the panel having an elongate slot in it the effective length of which is approximately an integral sub-multiple of the wavelength of the radiation with which the antenna system is to be used, a coaxial feed cable the central conductor of which is preferably connected to one longitudinal edge of the slot and the screen of which is preferably connected to the other longitudinal edge of the slot opposite the first connection, the feed cable connection to the slot is preferably made in such a way that the feed line is non-resonant at the operating frequency and is matched to the impedance of the antenna independently of the length of the feed cable, there being an electrically conductive radio wave reflector element for reflecting radio waves locat-

ed closely adjacent one side of the conductor panel and spaced apart from the said conductor panel such that said reflector element acts to reflect the signal radiated on that side of the conductive panel so as to augment the signal radiated in a desired direction; said radio wave reflector element taking the form of a conductive panel having a slot (i.e. an aperture) in it.

[0040] Preferably the slot is of such dimensions that the reflector element is tuned to produce a strong reflection towards the slot antenna at the frequencies used by the slot antenna for transmission and/or reflection of signals.

[0041] In other words the radio wave reflector element is a tuned resonator, tuned to approximately (within 20% of) the resonant frequency of the slot antenna.

[0042] As the radio wave reflector element is a tuned resonator, it can be placed closer than one quarter wavelength of the radiated radio waves to the slot antenna and still reflect a significant portion of the radio waves. Thus, the tuned resonator allows a compact antenna system to be made. Preferably the tuned resonator is placed closer than one quarter wavelength of the radiated radio waves to the slot antenna.

[0043] Preferably the radio wave reflector element is spaced from the slot antenna at a distance such that a radio signal transmitted from the slot antenna interferes constructively with a signal reflected back through or around the slot antenna by the radio wave reflector element, at a window of a lamp unit in which they are enclosed.

[0044] Preferably the radio wave reflector element comprises a conductive panel having a slot. The slot may be a void or may be filled with a non-conductive material. Preferably the conductive panel is mounted on a non-conductive panel. The conductive panel may be e.g. made of metal foil, the non-conductive panel e.g. of a plastics material.

[0045] Preferably the system of the second aspect of the invention forms part of a vehicle tracking system.

[0046] The arrangement according to the second aspect of the invention may be used in the first aspect of the invention as mentioned above. In that case the use of a tuned resonator as a radio wave reflector element behind the convex side of the optical reflector allows the lamp unit to be compact while effectively directing radio waves in the desired direction.

[0047] A third aspect of the present invention provides a lamp unit for a vehicle comprising a light source, a window through which the light is to be directed, and between the window and the light source a slot antenna the slot of which is aligned with said light source so that in use light from the light source passes through the slot of the slot antenna and out of the window.

[0048] In this way the slot antenna itself is conveniently integrated into the structure of the lamp unit and forms a functional part thereof, in addition to its radio wave receiving and transmitting role. Thus, a compact lamp unit having a slot antenna can be formed.

[0049] The above configuration is particularly useful when the light source comprises a row of LED's as the LED's can then easily be aligned with the antenna slot.

[0050] The slot antenna in the lamp unit according to the third aspect of the invention may be part of an antenna system according to the second aspect of the invention. In that way the lamp unit can be kept compact while radio waves are directed in the desired direction by the radio wave reflecting element (the tuned resonator).

[0051] The tuned resonator may comprise a conductive layer mounted on a non-conductive (and preferably low power factor) substrate as described above for the slot antenna under the first aspect of the invention. The substrate may optionally have a corresponding slot also as described above.

The lamp unit preferably forms part of a vehicle.

[0052] The third aspect of the present invention may be provided (e.g. as back lights) in a vehicle having one or more lamp units according to the first aspect of the present invention (e.g. as front lights).

[0053] In the above aspects of the invention there may be provided a means for varying the resonant frequency of the antenna and/or the radio wave reflecting element.

[0054] In general the slot of a slot antenna has a length of approximately half a wavelength of the signal which it transmits. Tuning of a slot antenna may be effected by adjusting the slot length and, to a lesser extent, by adjusting the slot width. Where a slot antenna is used together with a tuned resonator (as a radio wave reflector element) then in general the tuned resonator is slightly off-tune with respect to the slot antenna and as a result, a phase relationship between the two can be varied. This difference in phase enables the separation between the slot antenna and the tuned resonator to be varied. If a solid conducting sheet is used as a radio wave reflector element instead of a tuned resonator, then a phase change of 180° occurs on the reflection and the separation between the slot antenna and the solid conducting sheet should normally be a quarter wavelength for optimum reinforcement of the radiated signal in the forward direction.

[0055] Embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a schematic plan of an antenna system;
 Fig. 2 is a schematic front view of a slot antenna for use in a first embodiment of the present invention;
 Fig. 3 is a cross-sectional view of a lamp unit according to a first embodiment of the present invention;
 Fig. 4 is a front view of an optical reflector comprising a plurality of electrically conductive panels for use in the first embodiment of the present invention;
 Fig. 5 is a front view of a tuned resonator for use in the first embodiment of the present invention;
 Fig. 6 is a front view of a second embodiment of the

present invention;

Fig. 7 is a cross-sectional view of the second embodiment of the present invention;

Fig. 8 is a front view of a tuned resonator for use in the second embodiment of the present invention;

Fig. 9 is a schematic plan of an antenna system for use in a large haulage vehicle;

Fig. 10 is a schematic plan of an antenna system for use in an articulated haulage vehicle; and

Fig. 11 is a schematic diagram of a headlamp unit which does not have a radiation screen around its outer walls.

[0056] The proposed vehicle radio communication system involves the use of two antennas, each contained within a headlamp, rear lamp or tail lamp unit of a vehicle. In order to be sure that all transmission was suppressed, a thief would have to screen all possible antenna enclosures with conducting foil and consequently five screens would be necessary. Screening of this type would render the vehicle conspicuous during daylight and make driving impossible at night.

[0057] Fig. 1 is a schematic view of a vehicle radio communication system for receiving and transmitting radio waves containing information relating to the position of the vehicle. Mobile Control Unit 1 receives a location signal from GPS antenna 2 and communicates the details to a tracking base station via the slot antennas 4 and 5 each of which is positioned in a respective lamp unit of the vehicle. The antennas 4 and 5 are fed from the same source via a T-junction splitter unit 3 with suitable impedance matching. Fig. 1 shows the arrangement of the connections to the antennas 4 and 5 from the T-junction 3. The coaxial feed cables 6 and 7 from the T-junction to the antennas are required to be equal to each other in length and also to be equal to an integral number of half wavelengths of the operating signals within the coaxial feed cables 6 and 7.

[0058] The first criterion ensures that the modulated signals radiated from the antennas 4 and 5 are in phase, the second criterion ensures that each length of the coaxial feed cables 6 and 7 acts as a 1:1 transformer and that the impedance presented by each length of the cable at the T junction is equal to the impedance of the respective antennas 4 and 5. If the connection of an antenna is severed, either accidentally or as the result of a deliberate attempt at damage, then the impedance of the severed connection will become infinite. Consequently the impedance presented by the opposite end of the damaged cable at the T junction will also be infinite and the remaining half of the system will continue to operate, albeit, with some mismatch, at the T junction. If the second criterion were not satisfied, an infinite impedance at the connection to the antenna created by severing the cable could result in a negligible impedance at the T junction and render the second antenna inoperative also.

[0059] Ideally the characteristic impedance of cables

6 and 7 should be twice the characteristic impedance of cable 1a between the mobile control unit 1 and the junction splitter unit 3.

[0060] Turning now to each lamp unit, a slot antenna for transmitting and/or receiving radio waves is positioned within the body of each lamp enclosure. The construction of the slot antenna is illustrated in Fig. 2.

[0061] The slot antenna is formed by cutting a slot 8 in an insulating panel 9, the material of which has a low power factor at the frequency of the transmission. In this embodiment the slot 8 is an empty void and this ensures that the field of the E vector of the radiated wave travels through free space and is not diminished by the presence of insulating material of relatively high permittivity between the upper and lower edges of the slot. The slot 8 has an effective length which is approximately an integral sub-multiple of the wavelength of the radiation with which the antenna system is to be used.

[0062] Conducting foil 10 is attached to the entire area of the panel 9 with the exception of the slot 8. The signal to be transmitted is fed to the slot antenna via a supply cable: coaxial cable 11 which terminates in two separate leads 12. The leads 12 diverge and are attached to the upper and lower edges of the slot respectively as shown in Fig. 2. In this way the central conductor of the coaxial feed cable is connected to one longitudinal edge of the slot 8 and the screen of the coaxial feed cable is connected to the other longitudinal edge of the slot 8 at a location opposite the first connection.

[0063] In order to avoid standing waves in the coaxial cable, the antenna impedance is matched to the impedance of the coaxial cable. Matching can be achieved by the adjustment of "X", the distance between the end of the slot 8 and the points of connection 13 of the leads 12 to the slot 8, and by alteration of the length "d" of the divergent leads 12. The antenna impedance varies with the point 13 selected for connection and the divergent leads act as an impedance transformer. In this way it is ensured that the feed line is non-resonant at the operating frequency and is matched to the impedance of the antenna independently of the length of the feed cable.

[0064] Fig. 3 shows a cross-sectional side view of a headlamp unit according to the first embodiment of the present invention. The headlamp unit comprises a light source in the form of electrical lamp 50 and a slot antenna 8, 9, 10 both enclosed in an enclosure 15, 16, 55. A curved optical reflector 14 is positioned between the light source 50 and the slot antenna 8, 9, 10; it has a concave side adjacent the light source for reflecting light out of a window 55 at the front end of the enclosure and a convex side behind which the slot antenna 8, 9, 10 is positioned. In this way the slot antenna is concealed.

[0065] The slot antenna comprises an insulating panel 9 having an antenna slot 8 and electrically conducting metal foil 10 that is mounted on and covers the face of the insulating panel 9 except for slot 8, as described above. A coaxial feed cable (B) is connected to the antenna, as described above for supplying and/or receiving

a signal to or from the slot antenna. The coaxial feed cable (B) lies in a horizontal plane enclosing the central axis of the lamp unit antenna assembly. This horizontal plane also contains the axis of the slot of the slot antenna.

[0066] In conventional modern headlamp system the reflector consists of an insulating body with a metallic reflecting film. If an unmodified reflector of this type were to be used in the current assembly, then the signal from the antenna would cause currents to be induced in the metal coating of the optical reflector. As a result, severe attenuation of the transmitted signal from the antenna would occur. Consequently, it is necessary to modify the optical reflector so as to cause negligible attenuation of a radiated signal passing through it without impairing the operation of the optical system.

[0067] This is achieved by dividing the surface area of the optical reflector 14 into a plurality of portions of electrically conductive material for reflecting light from the light source 50 out of the lamp unit. The portions of electrically conductive material are electrically isolated from each other and induction of electric currents in the reflector is thus limited or prevented.

[0068] In the present embodiment the optical reflector 14 comprises an electrically conductive (metal) surface layer mounted on an electrically insulating (non-conductive) substrate. The metal layer is divided into a plurality of rectangular panels 60, approximately 1cm high x 2cm wide and arranged to form a grid as shown in Fig. 4. The panels 60 are electrically isolated from each other by the divisions (gaps) between them and supported by the insulating substrate. The function of the divisions between the panels is to prevent the vertical electric vector of the electromagnetic wave from inducing a current in the optical reflector. A scratch on the reflecting metal surface, provided it is deep enough to reach the insulating substrate, is sufficient to prevent the induction of currents in the reflector. The optical reflector 14 thus results in negligible attenuation of an electromagnetic wave transmitted through it. The pattern formed by the divisions between the panels 60 of the optical reflector 14 can be concealed by a ribbed structure in the lamp unit window 55. The circles C and D in Fig. 4 represent the location of the headlamp bulbs.

[0069] The conductors within the lamp unit, for example the sheath of a coaxial cable (B) within the lamp enclosure and the supply cable (A) for the headlamp bulb 50, lie entirely in a horizontal plane. If this condition was not satisfied, the vertical E field of the electromagnetic wave would induce a current in the conductor and the power radiated would be diminished.

[0070] The loss of energy from the lamp enclosure via the lamp supply leads can be reduced by the provision of chokes (not shown) consisting of helically wound coils in the supply leads (A) at the point of entry to the enclosure.

[0071] The headlamp enclosure shown in Fig. 3 has non-conducting (e.g. a plastics material) walls 15, 16 the

outer surfaces of which are coated with a conducting layer (e.g. a metal layer) to channel the radiated radio wave signal in the desired direction; in this case the direction of the central axis. In effect the outer conducting layer forms a screen and this screen is insulated from the slot antenna 8, 9, 10 by the insulating material of the enclosure walls 15, 16.

[0072] Approximately half the (radio wave) energy radiated by the slot antenna 8, 9, 10 is directed towards the rear of the headlamp enclosure (i.e. towards wall 15). A significant proportion of the energy is reflected back towards the front of the headlamp by a radio wave reflecting element in the form of tuned resonator 17 positioned between the slot antenna and the back wall 15 of the lamp unit.

[0073] In Fig. 3 the conducting enclosing on the outer surfaces of the walls 15, 16 channel the radiated signal in the direction of the central axis. This prevents radiation passing into the conducting enclosure formed by the inner surface of the metal car wing; as such radiation would essentially be trapped inside the car. This radiation would not play any part in communication with the distant receiving antenna and would consequently be wasted. The screen formed by the conducting layers has the additional advantage that the receiving signal from the distant transmitting antenna would be protected from locally generated interference, such as the engine ignition system and any cables buried beneath the road surface. However, it is becoming increasingly common for vehicles to have body panels which are formed of plastics material. In this case it becomes desirable for the lamp to be unscreened, that is it is better not to coat the outer surfaces of the lamp unit enclosure with a conducting layer. When there is no external screen, the radiation is able to pass through the sides of the lamp enclosure and contributes to the signal radiated towards the distant receiver as it is able to pass through the plastics material wings of the vehicle. Alternatively it would be possible to have an external screen over only a part of the outer surface of the lamp enclosure. The modified lamp, without an external screen or with only a partial screen over a limited area of its outer surface would have, for example, the following applications:

- (a) a headlamp mounted in a vehicle with plastics wings;
- (b) a fog lamp mounted within the plastics bumper of a vehicle;
- (c) a fog lamp mounted on a bar above the bumper of a vehicle;
- (d) a red fog lamp mounted at the rear of the vehicle as an additional rear light within a plastics rear bumper.

[0074] The effect of locally generated interference could be reduced by attaching a partial screen to the outer surface of the lamp enclosure or, alternatively by mounting a screen some distance away from the lamp

enclosure.

[0075] An alternative arrangement of a lamp enclosure and slot antenna without a screen is shown in Fig. 11. The figure shows a side view of the lamp with the axis of the slot antenna 3 perpendicular to the plane of the paper.

[0076] The lamp window is indicated by 55.

[0077] The plastics walls of the lamp enclosure are transparent to the radiation from the antenna and are indicated by 200. The slot antenna is indicated by 9.

[0078] A radiowave reflecting element for reflecting of the radiation towards the lamp window is indicated by 17. The element 17 could be a plane conducting sheet mounted parallel to the plane of the antenna at distance of a quarter wavelength from it. In this case, the virtual image 700 of the slot antenna is as far behind the radio wave reflecting element as the slot antenna is in front of it as shown in the diagram. Alternatively, the radio wave reflecting element could be in the form of a tuned resonator.

[0079] Part of the reflected radiation will pass through the walls of the enclosure as shown by the arrows 500.

[0080] Part of the radiation from the antenna will pass through the walls of the enclosure as shown by arrows 600.

[0081] A front view of a tuned resonator is shown in Fig. 5. The tuned resonator in this embodiment comprises a metal foil 17 attached to a non-conducting panel 17a (not seen in Fig. 5), of low power factor at the frequency in use, and the metal foil 17 has a slot enclosing an area 18 of the panel. It is, in effect, a slot antenna tuned to a frequency determined by the dimensions of the area 18 which are adjusted to give a strong reflection towards the front (i.e. towards the window 55) of the headlamp enclosure.

While a radio wave reflecting element consisting simply of a rectangular conducting sheet could be used instead of a tuned resonator, if a simple reflecting sheet was used the distance from the slot antenna to the radio wave reflecting element would need to be approximately a quarter wavelength of the radiation transmitted. The use of a tuned resonator enables this separation to be reduced. The tuned resonator is also selective in its response and consequently the antenna system is less susceptible to interference when acting as a receiver.

[0082] Use of a tuned resonator has been found to increase the slot antenna output. In one experiment the slot antenna output was found to increase by 130% compared to the output with the tuned resonator removed. The details of this experiment are as follows:

frequency of transmitter 911.6 MHz
 antenna slot dimensions: 15.3 cm x 1.65 cm
 resonator slot dimensions: 9.1 cm x 6.4 cm
 separation of slot antenna and resonator: 6.5 cm or 0.2 x wavelength

[0083] The antenna slot dimensions set out above

have been found to give good results. A wide slot tends to present problems with the spacing of the tapered transmission line. The tuned resonator is, in effect, a parasitic antenna receiving power from the driven antenna (the slot antenna) and it does not require any form of connection to a coaxial cable. In general, a significant range of adjustment is possible as a consequence of the many variables involved in the design.

[0084] While in the above embodiment the optical reflector is divided into a plurality of electrically conductive portions by mounting metal panels or scoring a metal layer mounted on an insulating substrate, a similar result could be achieved by applying metallic paint to the non-conducting surface of the insulating substrate instead. Metallic paint consists of conducting metallic particles in a binding medium. When the paint is dry the metallic particles are insulated from each other and consequently circulating currents do not occur in the reflector surface.

[0085] A second embodiment of the present invention will now be described. Many motor vehicles have a stop lamp unit consisting of a series of light emitting diodes arranged in a horizontal line and mounted behind a rear window of the unit. It is envisaged that the second embodiment of the present invention will be particularly suitable for use with this type of lamp unit.

Fig. 6 is a front view of a lamp unit of the above type modified to act also as a slot antenna for use in vehicle radio communication system as described above. An array of light emitting diodes 21 is mounted immediately behind an antenna slot 19 of a slot antenna. The light emitting diodes (LEDs) are aligned with the slot 19 of the slot antenna so that light from the LEDs is directed through the slot 19. The slot 19 is cut in a panel of non-conducting material and conducting metal foil 20 is attached to the area of the panel surrounding the slot 19. The slot antenna is fed and the impedance is adjusted in the manner described above for the first embodiment.

[0086] Fig. 7 shows a side view of the lamp unit of the second embodiment. An enclosure 23 formed of insulating material encloses the row of light emitting diodes 21 which are carried on a non-conducting strip 22 mounted immediately behind the slot 19 of a slot antenna. The slot antenna is formed within one wall of the enclosure 23. The supply cable (A) for the diodes and the coaxial feed cable (B) for the antenna lie in a horizontal plane passing through the central axis of the lamp unit enclosure 23.

[0087] Radio waves from the slot antenna which travel towards the rear of the enclosure (i.e. towards the rear wall 70) are reflected by a tuned resonator 24 as described above for the first embodiment. The tuned resonator 24 is positioned between the slot antenna and the rear wall 70 of the enclosure 23 as described above for the first embodiment. Preferably its spacing from the slot antenna is less than $\frac{1}{4}$ wavelength of the radiation frequency used by the antenna.

[0088] The external surface of the insulating enclosure 23 is covered by a conducting layer 101 in order to confine the radiation in the direction of the lamp axis.

[0089] Fig. 8 illustrates the construction of the tuned resonator. Metal foil 25 is attached to an insulating panel 25a (not seen in Fig. 8 which is a front view) with the exception of slot area 26 where there is no foil. The resonator therefore acts as a slot antenna and is tuned to give a strong reflection at the transmission frequency. Alternatively, insulating material could be removed from the slot area 26 to create a void. This would result in a resonator of higher 'Q' with sharper tuning than the previous arrangement.

[0090] In the above embodiments the coaxial lines used to connect the antennas to the transmitter are unbalanced lines. The antennas described above would tend to act as a balanced load and the arrangements described therefore should be understood to include where necessary the introduction of an unbalanced-to-balanced transformer or balun between the coaxial lines and the antenna.

[0091] The arrangements described above are suitable for application to motorcars and slightly larger vehicles. However, the antenna system could also be fitted to large haulage vehicles, including articulated vehicles consisting of a tractor and coupled trailer. While the antenna(s) would be mounted in the lamp unit(s) as described above, the connection of the antenna and the configuration of the system may require some adjustment due to the greater distances involved. For example, in these cases the stop lamp unit would probably be mounted at the highest point at the back of the truck or trailer.

[0092] This arrangement would require a rear coaxial connection cable of considerable length and this would result in significant attenuation of the signal radiated from the rear of the vehicle. In these applications the rear lamp unit would include a radio frequency amplifier to maintain the radiated signal strength. The amplifier would be powered from the vehicle low voltage dc power supply and, by the use of appropriate radio frequency filters, the dc supply could be conveyed to the amplifier over the coaxial connection system.

[0093] The general arrangement for a large haulage vehicle system is illustrated by Fig. 9.

[0094] The front headlamp antenna 4 is connected to the junction splitter unit 3, in the manner previously described, via coaxial cable 6. The second coaxial cable 30 leads to the rear stop light assembly of the vehicle 33 which contains the amplifier to compensate for the attenuation of the transmitted signal along the cable 30.

[0095] The following criterion should be applied in this modification of the original system:

[0096] The leads 6 and 30 should be of such a length that they contain an integral number of half wavelengths of the operating signal within the transmission lines. This requirement, which is described in GB patent number 2341504, ensures that one antenna would continue to

operate if the coaxial cable to either antenna is severed at the lamp assembly.

[0097] Fig. 10 illustrates the arrangement for an articulated vehicle consisting of a tractor and coupled trailer.

[0098] The front headlamp antenna is connected to the junction splitter unit 3 via a coaxial cable 6. The second coaxial cable 31 leads to a coaxial interconnector 27 between the tractor and trailer of the articulated vehicle. The coaxial cable 32 travels along the trailer to the rear light assembly and amplifier unit 33.

[0099] The following criteria should be applied in this modification of the original system:

[0100] The leads 6 and 31 should be of such a length that they contain an integral number of half wavelengths of the operating signal within the transmission lines. This requirement, which is described in GB patent number 2341504, ensures that the front headlamp antenna would continue to operate if the connection between the tractor and trailer were broken at the point 27 in order to move the tractor without its associated trailer.

[0101] The coaxial cable 32 between the connector 27 and the rear lamp assembly should contain an integral number of half wavelengths of the operating signal to ensure that the headlamp antenna will continue to operate if the coaxial cable is severed at the stop lamp assembly.

[0102] The coaxial cable interconnector between the tractor and trailer should be part of a multiple connector carrying the power supplies to the trailer. This arrangement will ensure that it is not possible to break the antenna connection without disrupting all the trailer power supplies.

[0103] Both the arrangements described above will result in a time delay between the signals radiated from the front and rear antennas. With the cable lengths involved, the time delay is extremely short. In the unlikely event that the delay causes problems with transmission on a cellular network, the cables from the junction splitter unit to both antennas may be made equal in length, suitable amplification would then be required for both the front and rear antennas.

[0104] In all of the above embodiments slot antenna are used. Generally the slot antenna comprises a slot cut in a (preferably rectangular) conducting panel. Usually the conducting area surrounding the slot (which is a void or filled with non-conductive material, in either case being a non-conductive region of the antenna) is of the order of ten times the area of the slot. In order to produce vertically polarised radiation the antenna should be positioned with the slot substantially horizontal.

Claims

1. A lamp unit for a vehicle comprising a curved optical reflector having a convex side and a concave side for reflecting light out of the lamp unit, a light source

positioned adjacent to the concave side of the optical reflector, and a slot antenna positioned opposite the convex side of the optical reflector for transmitting and/or receiving radio waves, the concave side of the optical reflector comprising portions of electrically conductive material for reflecting light out of the lamp unit, said portions of electrically conductive material being electrically isolated from each other so as to limit induction of electrical currents in the reflector, the optical reflector further comprising an electrically non-conductive material for supporting or holding together said portions of electrically conductive material.

2. A lamp unit according to claim 1 wherein the reflector comprises a layer of metallic paint containing metallic particles in an electrically non-conductive binding medium.
3. A lamp unit according to claim 1 wherein said electrically non-conductive material takes the form of a substrate and the portions of electrically conductive material are a plurality of panels of electrically conductive material mounted on the substrate.
4. A lamp unit according to claim 3 wherein the panels are arranged in a matrix or wherein the panels are in the form of elongate strips aligned parallel to the longitudinal extent of the antenna slot so as to keep the strips perpendicular to the E vector of transmitted or received radiation.
5. The lamp unit of any one of the above claims wherein the lamp unit comprises an enclosure enclosing the light source, optical reflector and slot antenna, having a window at one end facing the concave side of the optical reflector, so that light reflected by the optical reflector can pass out of the window.
6. The lamp unit of claim 5 wherein the outer walls of the enclosure are formed of a non-conductive material.
7. The lamp unit of claim 6 wherein the outside surfaces of said walls are coated with a conductive material.
8. The lamp unit of any one of the preceding claims wherein the conducting cables of the unit lie substantially entirely in the plane in which the longitudinal axis of the slot of the slot antenna lies or in a plane parallel thereto.
9. The lamp unit of any one of the preceding claims wherein cables for supplying electricity to the light source are provided with chokes.
10. The lamp unit of any one of the preceding claims

wherein the slot antenna has a coaxial feed cable the central conductor of which is connected to one longitudinal edge of the slot of the antenna and the screen of which is connected to the other longitudinal edge of the slot opposite the first connection, the connection points being chosen such that the feed line is non-resonant at the operating frequency of the antenna and is matched to the impedance of the antenna.

11. The lamp unit of any one of the preceding claims further comprising a radio wave reflector element located adjacent the side of the slot antenna which faces away from the convex side of the optical reflector.

12. The lamp unit of claim 11 wherein the radio wave reflector element is a conductive panel substantially parallel the plane of the slot antenna and spaced apart from the slot antenna by a distance approximately one quarter wavelength of the resonant frequency of the slot antenna.

13. The lamp unit of claim 11 wherein the radio wave reflector element is a resonator in the form of a conductive panel having a slot in it, said resonator being tuned to resonate at a frequency not differing by more than 20% from the resonant frequency of the slot antenna.

14. A slot antenna system for use in a vehicle radio communication system, comprising an electrically conductive panel adapted to be carried by or to form part of the structure of the vehicle, the panel having an elongate slot in it, the effective length of which is approximately an integral sub-multiple of the wavelength of the radiation with which the antenna system is to be used, a coaxial feed cable the central conductor of which is connected to one longitudinal edge of the slot and the screen of which is connected to the other longitudinal edge of the slot opposite the first connection, the feed cable connection to the slot is made in such a way that the feed line is non-resonant at the operating frequency and is matched to the impedance of the antenna independently of the length of the feed cable, there being an electrically conductive radio wave reflector element for reflecting radio waves located adjacent one side of the conductive panel and spaced apart from the said conductive panel such that said reflector element acts to reflect the signal radiated on that side of the conductive panel so as to augment the signal radiated in a desired direction; said radio wave reflector element taking the form of a conductive panel having a slot in it.

15. A lamp unit for a vehicle comprising a light source, a window through which the light is to be directed,

and between the window and the light source a slot antenna the slot of which is aligned with said light source so that in use light from the light source passes through the slot of the slot antenna and out of the window.

16. A lamp unit according to claim 15 wherein the light source comprises a row of LEDs aligned with the slot of the slot antenna.

17. A vehicle tracking system comprising a lamp unit according to any one of claims 1 to 13 or 15 to 16 or a system according to claim 14, wherein the vehicle tracking system comprises means for determining the position of the vehicle from radio waves, means for producing vehicle position data signals based on the received radio waves and means for causing said slot antenna to communicate said vehicle position data signals to a base tracking station.

18. A lamp unit according to claim 14 wherein said reflector element is a resonator tuned to resonate at a frequency not differing by more than 20% from the resonant frequency of the slot antenna.

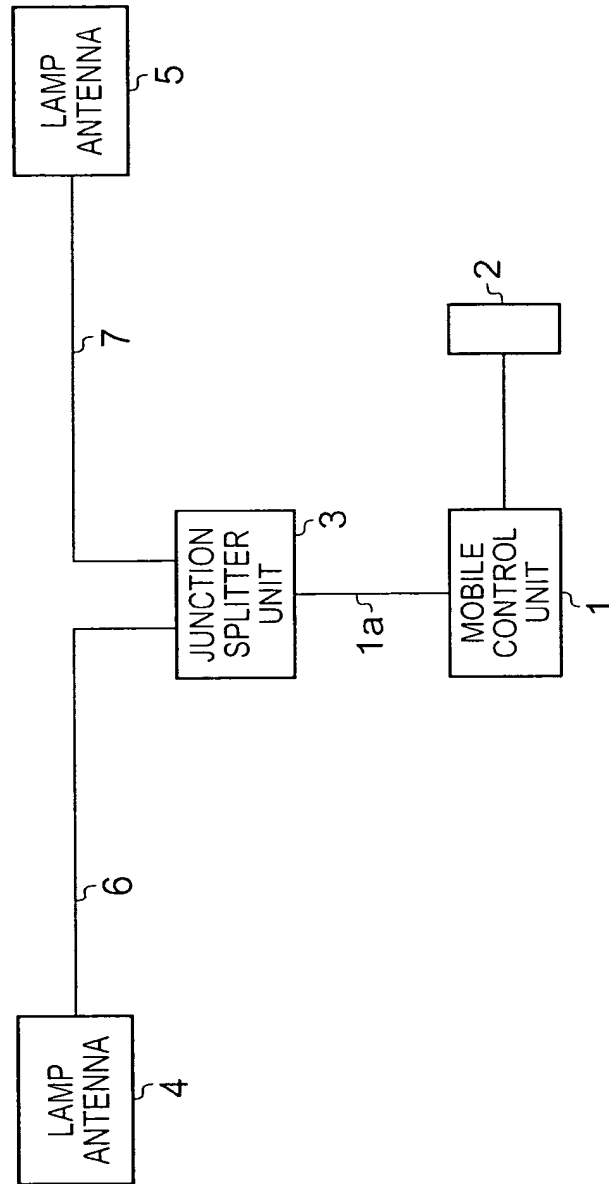


Fig. 1

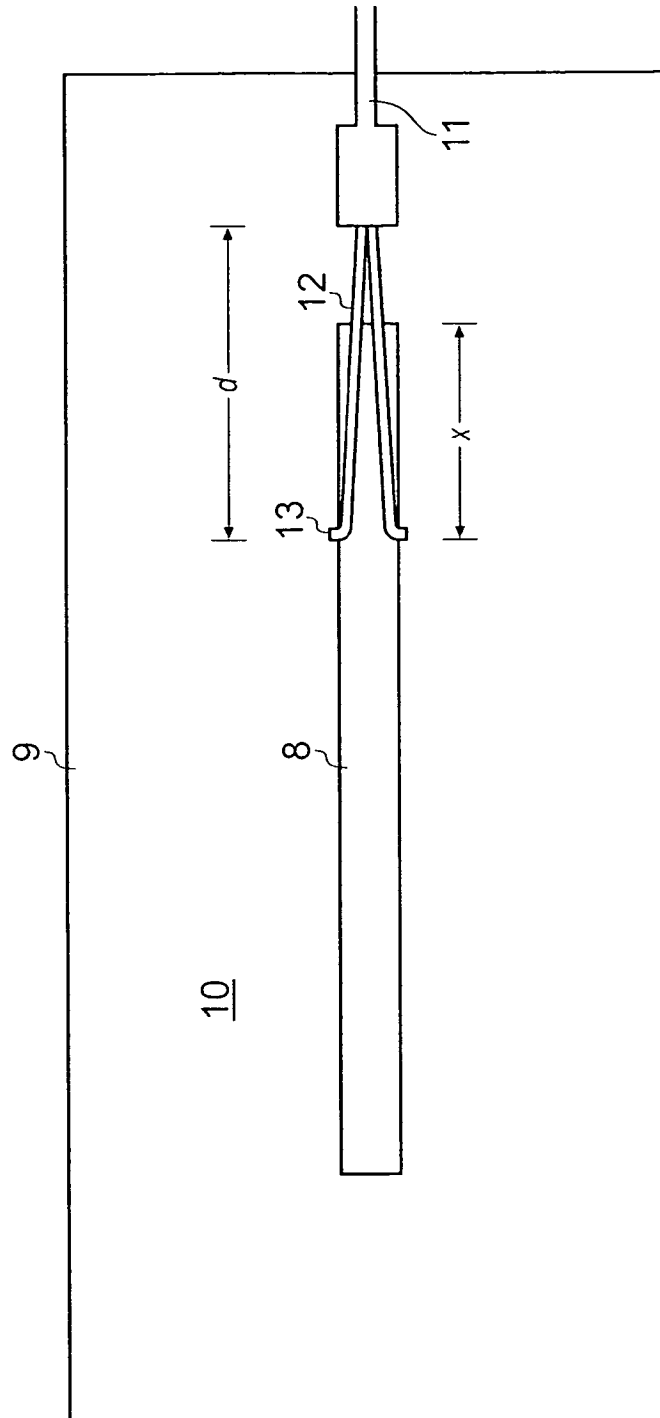


Fig. 2

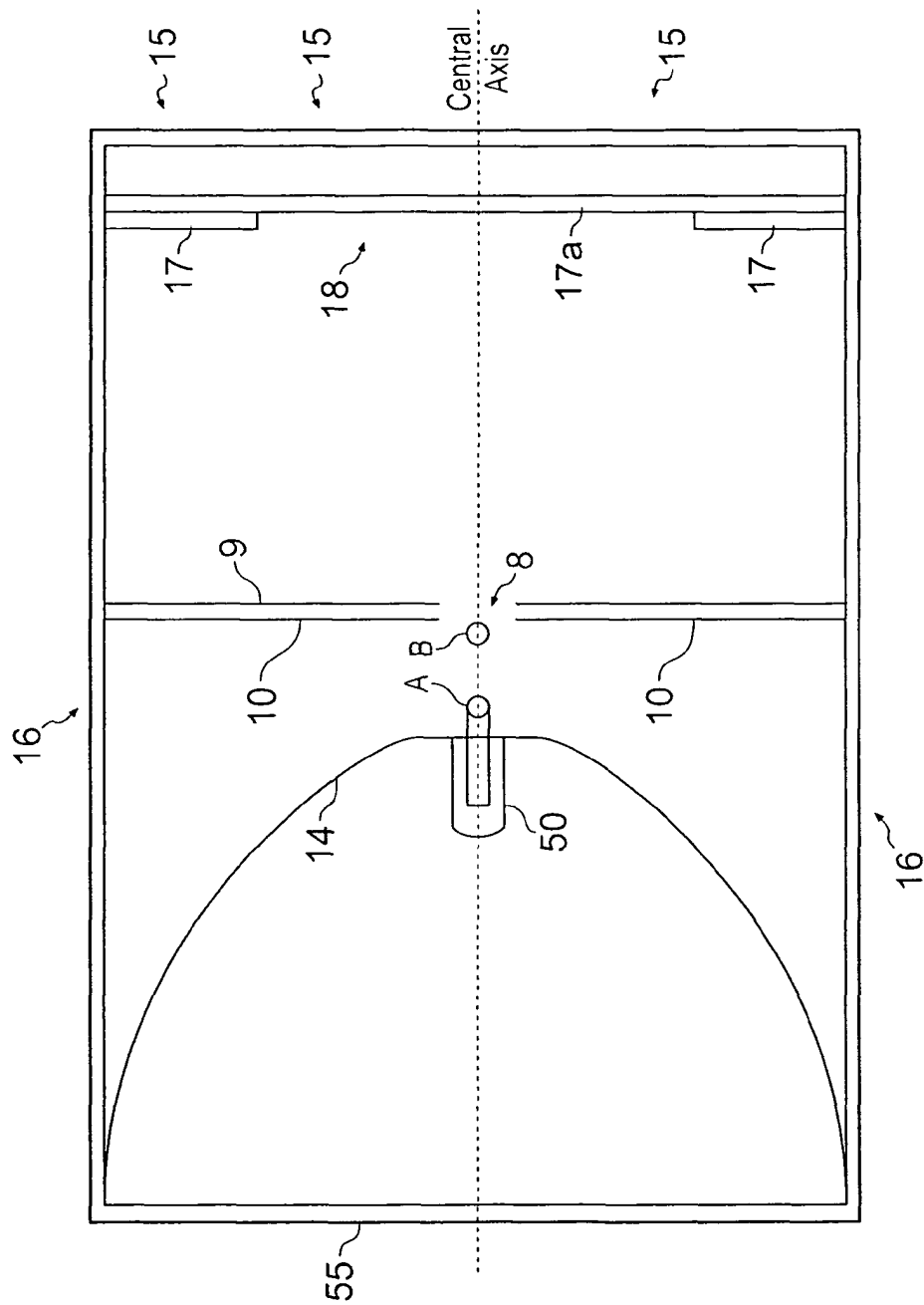


Fig. 3

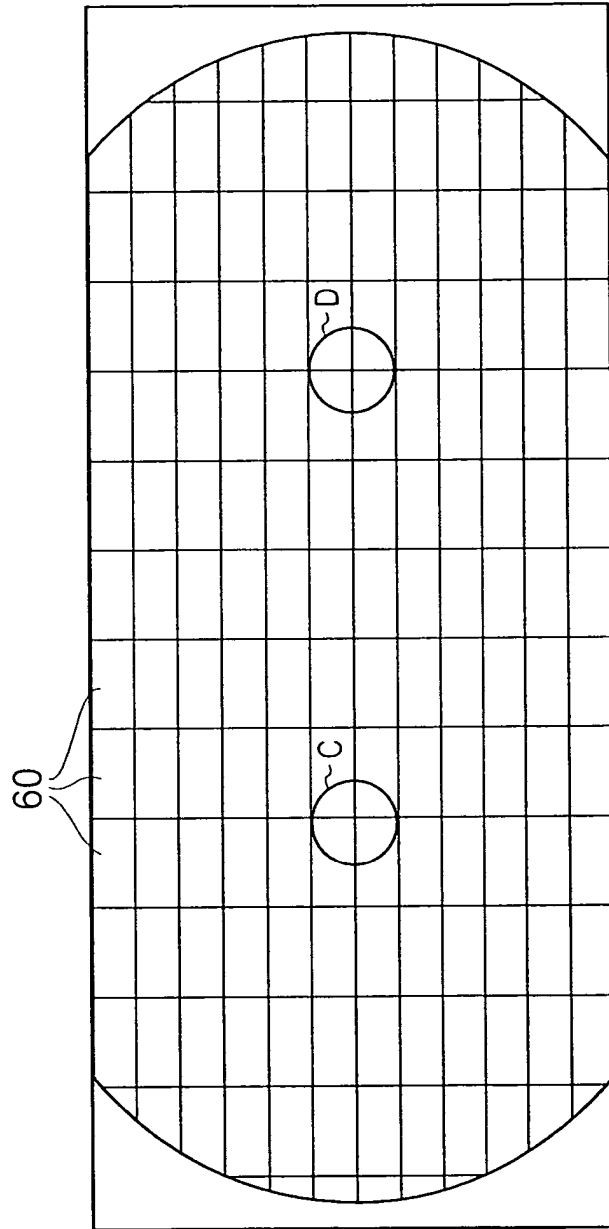


Fig. 4

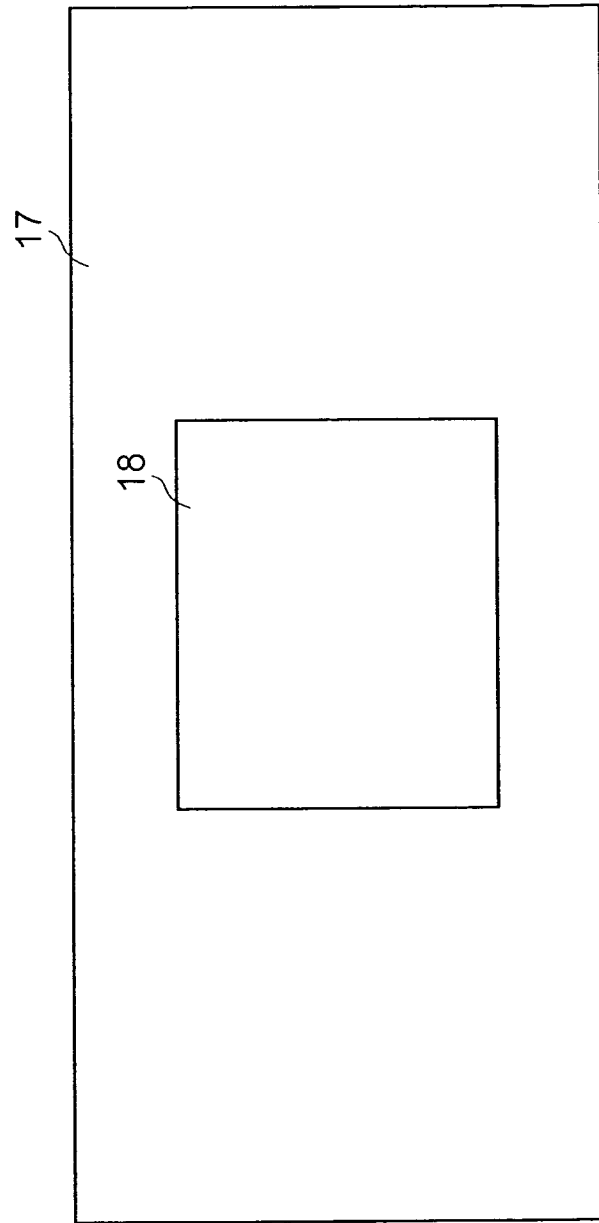


Fig. 5

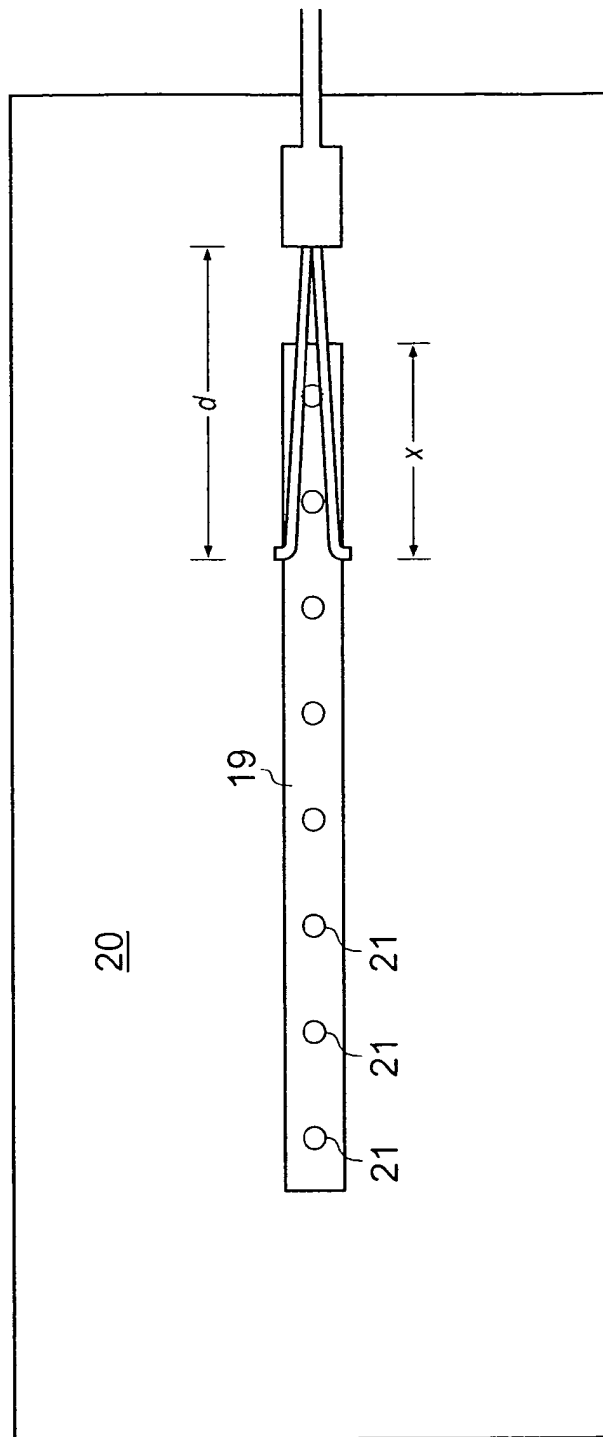


Fig. 6

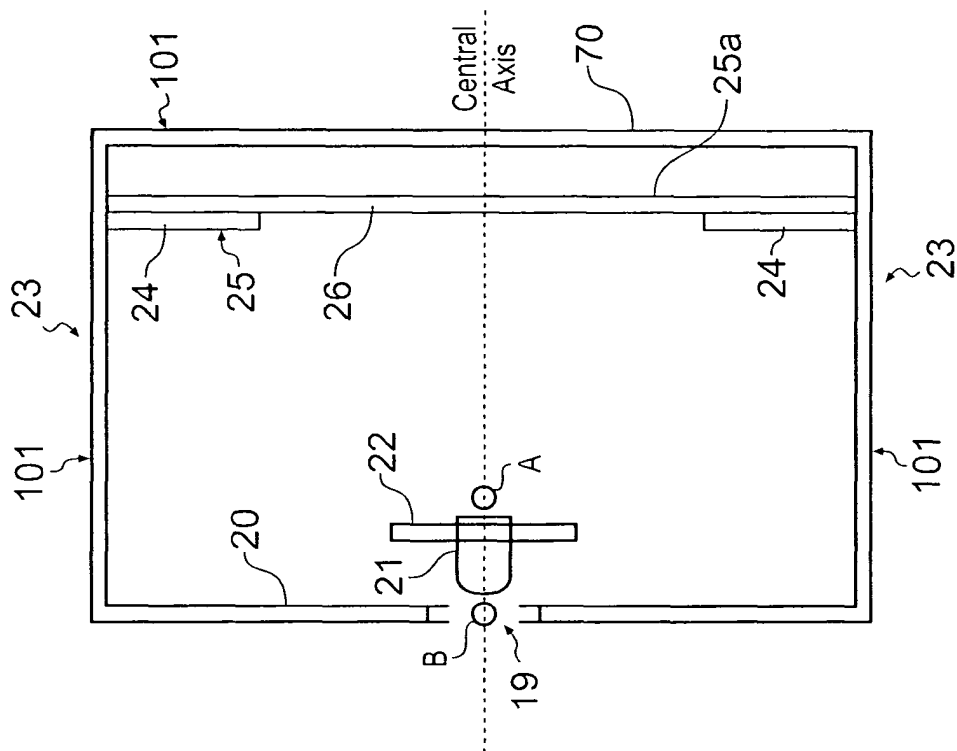


Fig. 7

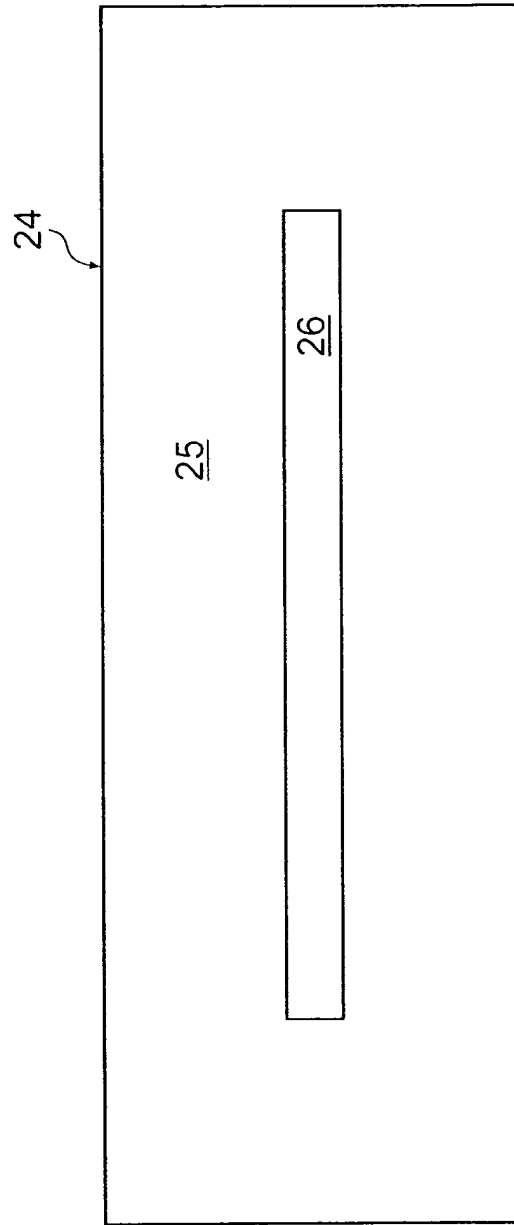


Fig. 8

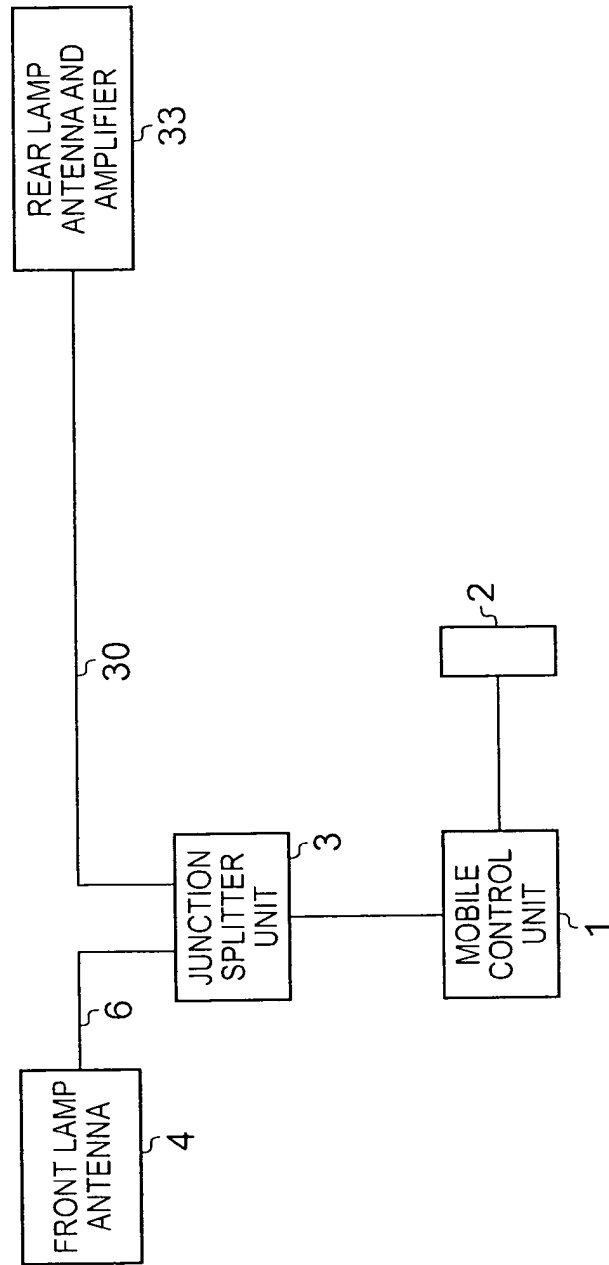


Fig. 9

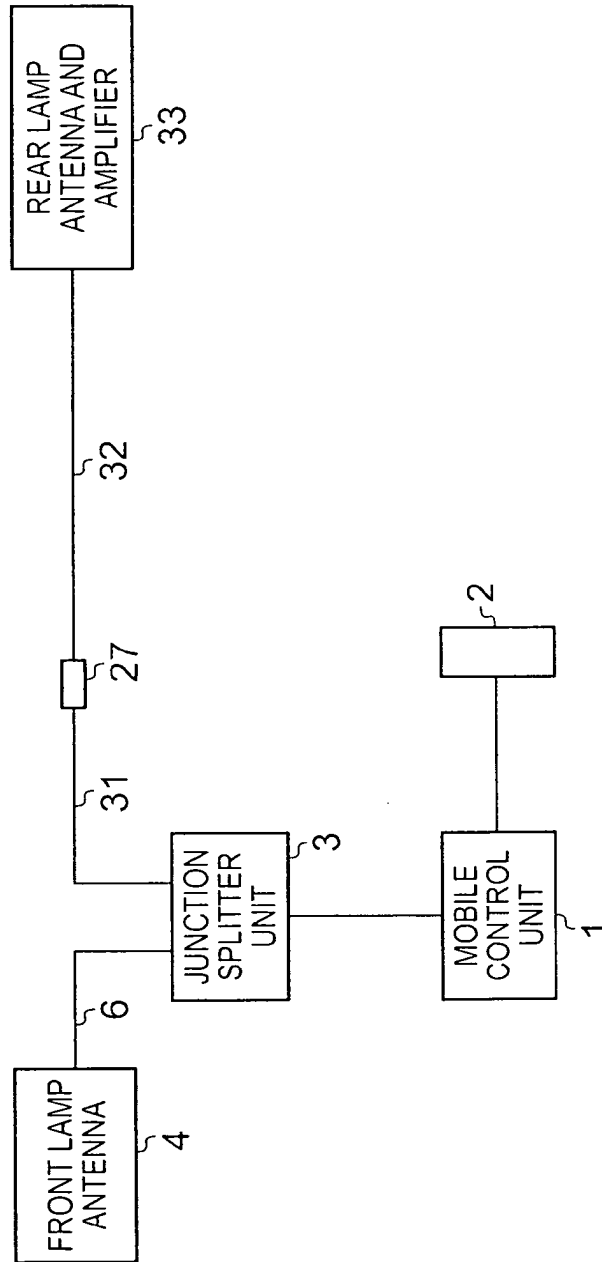


Fig. 10

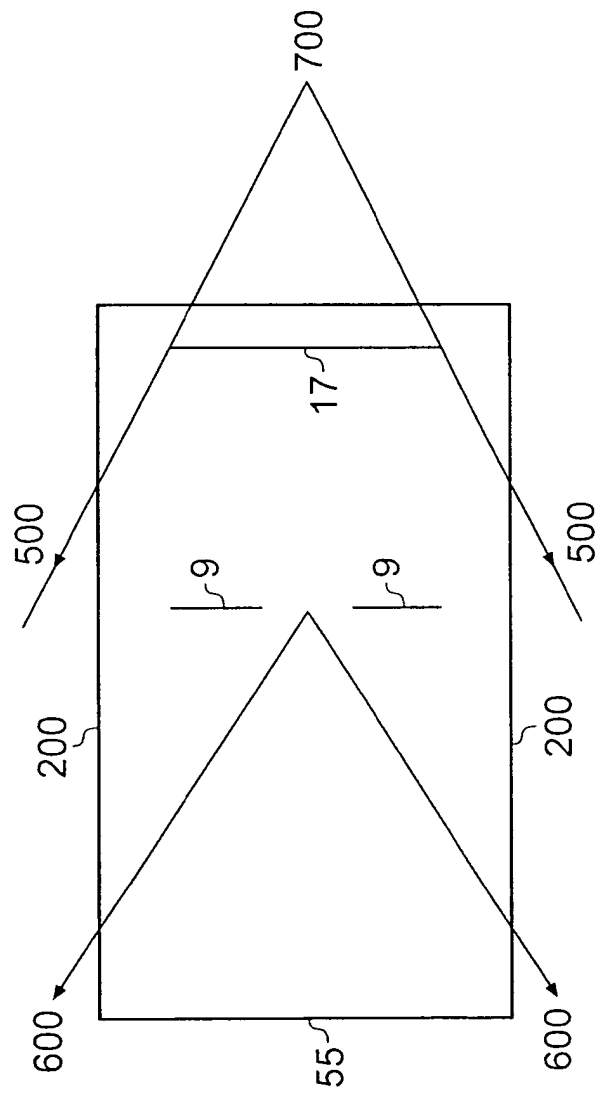


Fig. 11



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 25 4393

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Place of search		Date of completion of the search	Examiner
The Hague		15 November 2004	Moumen, A
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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