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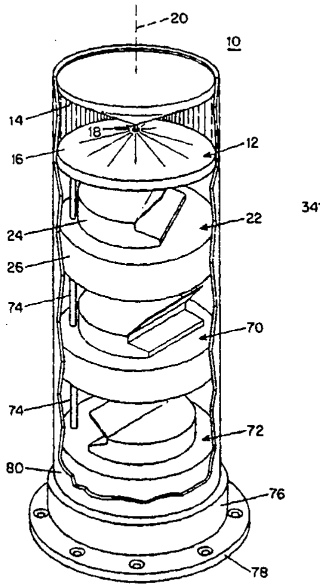

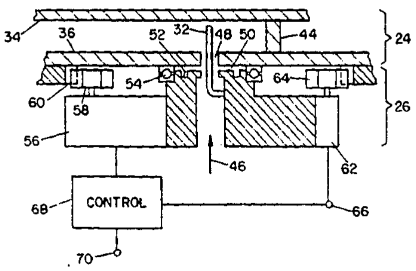

(57) Abstract

A 60 GHz LAN antenna uses a simplified rotary joint to enable antenna steering. A lower gain omnidirective antenna (12) used for signal acquisition is coaxially mounted with a steerable directive antenna (22) used for communication. The steerable antenna (22) includes a reflector (24) rotatable about a central axis (20) with the rotatable section of a simplified rotary joint (Fig. 2C). A waveguide (46) is coupled to the fixed portion of the rotary joint and signals are coupled from the waveguide to the reflector via a probe element (32) which is positioned on the central axis. This combination, enabling use of direct waveguide-to-reflector signal coupling, overcomes the need for a waveguide-to-waveguide or a coax-to-coax rotary joint. Three or more steerable antennas (22, 70, 72) can be coaxially stacked with one omnidirective acquisition antenna (12) and automatic steering can be implemented to communicate in different directions. Particular embodiments use a pillbox antenna (24) or dielectric lens (84).

STEERABLE ANTENNA SYSTEMS

This invention relates to steerable antennas and, more particularly, to directive antennas which can be vertically ganged and rotated for communication in different directions selected based upon signal acquisition by a lower gain omnidirective antenna.

BACKGROUND OF THE INVENTION

In an application such as a wireless local area network (LAN) for mobile field use, it would be desirable to be able to mount an antenna on the roof of a vehicle for communication with one or more other nodes. Each such node could use a similar transmit/receive antenna serving mobile radio equipment or a fixed radio communication site, for example. While an omnidirective antenna would provide the capability of receiving signals from any direction or azimuth angle, and over a reasonable range of elevation angles, the gain of such antennas may be too low for limited transmission power applications. Use of directional antennas could solve the antenna gain problem, however electronically steered directional antennas have generally been too complex and expensive for such applications and mechanically steered antennas have generally necessitated use of rotary joints.

Two general types of rotary joints have been known. A waveguide rotary joint typically includes, in series, a transition from rectangular to circular waveguide utilizing a polarizer or mode converter, a non-contacting rotary choke, and a circular to rectangular waveguide transition utilizing a second polarizer or mode converter. While providing good performance, such a waveguide rotary joint is complex, expensive and of extended size relative to the waveguide dimensions. A coaxial rotary joint typically includes a transition from a fixed coaxial line to a rotatable coaxial line section relying upon mechanical spring finger contacts, which make rubbing contact with the center and outer conductors at the transition. Such physical contact arrangements may introduce limitations as to performance, reliability and useful life.

It may be desirable to provide a wireless local area network operating at higher frequencies, such as in the extremely high frequency (EHF) range in the vicinity of 60 GHz. At such frequencies increased attenuation of transmitted signals by oxygen absorption is helpful in minimizing self-interference and inter-system interference, and in greatly reducing the probability of data interception by unauthorized parties. However, at these frequencies the wavelength is so small that it becomes impractical or overly expensive to fabricate all the components of a typical waveguide rotary joint. Also, for a coaxial rotary joint the coaxial line becomes very small in view of constraints regarding prevention of higher mode propagation. As a result, fabrication and use of the required inner conductor contacts becomes impractical.

It is therefore an object of this invention to provide new forms of steerable antennas and such antennas usable in antenna systems which may include a plurality of such antennas.

It is a further object to provide mechanically steerable antennas utilizing improved and simplified rotary joints in accordance with the invention.

It is also an object to provide new steerable antennas suitable for mobile or fixed use in wireless local area networks and particularly such networks operating at higher frequencies.

Additional objects are to provide new and improved antennas and antenna systems which avoid one or more disadvantages or limitations of prior devices.

SUMMARY OF THE INVENTION

A steerable antenna includes a collimator rotatable about a central axis and a circular choke aligned with the central axis and having a movable portion rotatable with the collimator and a fixed portion cooperating with the movable portion. A transmission line section is aligned with the central axis and coupled to the fixed portion of the choke. Coupling means, including probe means aligned with the central axis, is provided for coupling signals from the collimator to the transmission line section. Rotation means, coupled to the movable portion of the choke, enable the collimator to be rotated for signal reception from a desired direction.

A steerable antenna system includes a first antenna having a wide antenna pattern able to receive signals from a range of directions relative to a central axis. A second antenna includes focusing means rotatable about the central axis and providing a more directive antenna pattern than the first antenna, a circular choke having a movable portion rotatable with the focusing means and a fixed portion cooperating with the movable portion, a transmission line section coupled to the fixed portion of the choke, and coupling means for coupling signals from the reflector to the transmission line section. Rotation means, coupled to the movable section of the choke, enable the focusing means to be rotated toward the direction of a first signal received by the first antenna to permit the second antenna to receive the first signal. Steering means are coupled to the movable section of the choke for rotating the reflector and control means, coupled to the steering means and responsive to the first signal, enable the steering means to rotate the reflector until the first signal is received by the second antenna.

For a better understanding of the invention, together with other and further objects, reference is made to the following description taken in connection with the accompanying drawings and the scope will be pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a steerable antenna system in accordance with the invention which includes one omnidirective antenna and three steerable directive antennas.

Figs. 2A, 2B and 2C show details of a steerable antenna of Fig. 1.

Figs. 3A and 3B illustrate a dielectric lens embodiment of a steerable antenna using the invention.

Figs. 4A and 4B show an alternate form of probe configuration for use in a steerable antenna in accordance with the invention.

DESCRIPTION OF THE INVENTION

Fig. 1 shows a steerable antenna system 10 utilizing the present invention. For use in a wireless LAN operating in the vicinity of 60 GHz, typical dimensions of the Fig. 1 antenna system may approximate a height of less than twelve inches with a cylindrical radome diameter of about three inches. As shown, the Fig. 1 system includes a first antenna 12, shown as a bi-conical horn antenna, having a wide or omnidirective antenna pattern. Antenna 12 includes upper and lower conical reflector surfaces 14 and 16 forming an omnidirective horn which is fed by the extended center conductor 18 of a simple coaxial feed at a transition to coaxial line from a waveguide feeding the antenna. With this configuration, antenna 12 provides relatively low gain omnidirective coverage to enable reception of signals from a range of directions from 0° to 360° relative to a central axis 20 passing through the center of the antenna system 10.

The Fig. 1 antenna system also incorporates a second antenna, shown as steerable pillbox type antenna 22. In this embodiment, antenna 22 includes two basic sections, a rotatable focusing (e.g., reflector) assembly 24 and a base assembly 26. Referring now to

Figs. 2A, 2B and 2C, features of antenna 22 are illustrated in greater detail. Fig. 2A shows in simplified form a plan view of the focusing assembly 24, including a collimator shown as parabolic reflector 28 which is rotatable, as indicated by arrow 30, about central axis 20 of Fig. 1 . In Fig. 2A, axis 20 passes through signal coupling means shown as a monopole feed or probe 32, which is mounted from below so as to lie at the focus of the reflector 28. Thus the focus of reflector 28 falls on the central axis 20, the reflector is rotatable about axis 20 and, as a result, the fixed probe 32 always remains at the focus of the reflector 28 as the reflector rotates. As used herein, "collimator" refers to a device, such as a reflector or lens, for focusing divergent ray paths to a substantially parallel relationship, or vice versa.

As seen in the simplified cross-sectional side view of Fig. 2B, the pillbox type focusing assembly 24 includes upper and lower planar reflective surfaces 34 and 36 and angled entrance flaps 38 and 40, which are effectively extensions of surfaces 34 and 36. The focusing assembly 24 thus includes a narrow parabolic reflector 28, which provides focusing as indicated by the ray path arrows 42 in Fig. 2A, and angled flaps 38 and 40, which are proportioned to provide a level of elevation directivity. As shown, the focusing assembly also includes a sub-reflector, shown as flat surface 44, which serves to reflect signals radiated toward it (from omnidirective probe or monopole 32) back toward parabolic surface 28. With an understanding of the invention, skilled persons familiar with prior pillbox antennas will be enabled to provide specific design features and dimensions appropriate to particular applications. Thus, it will be understood that elements in Figs. 2A and 2B will typically be constructed of metal sections of finite thickness, although thickness is not shown in these simplified views. As will be discussed below with reference to Figs. 3A and 3B, in other embodiments the focusing element may be a dielectric lens rather than the parabolic reflector of Fig. 2A.

Referring now to Fig. 2C, there is shown an expanded view of a portion of the Fig. 2B focusing assembly, together with directly associated portions of the base assembly 26 (which underlies focusing assembly 24, as shown in Fig. 1). In Fig. 2C, signals radiated by monopole 32 travel to the left, directly or after reflection from sub-reflector 44, and are reflected by the parabolic reflector (not included in this sectional view) to leave the antenna as a beam directed to the right, as indicated by ray path arrows 42 in Fig. 2A. Reference is now made to the elements of base section 26 appearing below lower pillbox reflective section 36 in Fig. 2C. As illustrated, a section of transmission line, shown as waveguide section 46, is positioned in alignment with an opening 48 through which the monopole probe radiator 32 extends into its position between sub-reflector 44 and main parabolic reflector 28. The monopole or probe 32 is supported in known manner from the side of the waveguide 46, so that the probe will remain in fixed position at the focus of the reflector as the reflector assembly rotates around it.

As shown in Fig. 2C, second antenna 22 of Fig. 1 also includes a circular non-contacting choke 50 having a fixed section and a movable section which is rotatable with parabolic reflector 28. The fixed section of choke 50 comprises the upper surface of the mechanical structure defining the waveguide section 46 and includes a circular channel 52. The movable section of choke 50 comprises the lower surface of the portion of the lower section 36 of the reflector assembly 24 which surrounds the opening 48. It will thus be seen that, consistent with prior designs of circular chokes, this combination of the lower surface of section 36 and the upper surface of the structure forming waveguide 46, incorporating the circular channel 52, provides a circular choke 50 effective to constrain signals within the waveguide/probe signal channel, without requiring electrical contact between the rotatable upper section and the fixed lower section of the choke. It will further be appreciated that this result is accomplished without requiring either contacting fingers or a multitude of precision machined parts, which may be very expensive or physically impractical to provide for higher frequency applications, such as the EHF range wireless LAN network discussed above.

Other components of the base assembly 26 of antenna 22 may appropriately include rotation means, coupled to the movable section of the choke 50, to enable the reflector assembly 24 to be rotated toward the direction of desired signal reception or transmission. As shown in Fig. 2C, the rotation means includes a circular ball bearing assembly 54 rotatably coupling the reflector assembly 24 to the base assembly 26. Any arrangement suitable for enabling the desired rotation may be employed, including arrangements as simple as cooperating surfaces coated with a suitable low friction durable substance. No electrical contact is required to be provided by the bearing or other rotation means with the use of a choke such as shown. As illustrated, the base assembly 26 also includes steering means shown as motor 56 controlling a drive gear 58, which drives a circular ring gear 60, and a resolver 62 activated by a gear 64 which is driven by ring gear 60. In response to control signals, motor 56 causes drive gear 58 to rotate the reflector assembly 24 by driving the ring gear 60. Resolver 62 provides signals at terminal 66 which represent reflector position data responsive to rotation of drive gear 64 by ring gear 60, which is under the positioning control of the motor 56. In other applications, items 56 through 66 may be omitted and the reflector assembly 24 may simply be rotated to a desired position manually as permitted by the rotation means, shown as bearing assembly 54.

As indicated by block 68 in Fig. 2C, an antenna system incorporating antenna 22 may also include control means 68, coupled to motor 56 of the steering means. Motor 56 is thus responsive to signals input at terminal 70 which are indicative of a direction to which it is desired to rotate the reflector for reception of signals from a transmitter lying in that direction, for example. As shown, control means 68 is also responsive to signals from resolver 62 representative of the direction to which the focusing means has currently been rotated.

Returning now to Fig. 1, it will be seen that the antenna system 10, as illustrated, additionally includes a third antenna 70 and a fourth antenna 72, each consisting of a steerable pillbox type antenna of the same form as the second antenna 22. Each of the antennas 70 and 72 thus includes a reflector, a sub-reflector, a circular choke, a transmission line section, coupling means, rotation means and steering means as shown in, and described with reference to, Figs. 2A, 2B and 2C. As will be further discussed, control means 68 of Fig. 2C may be configured for control of each of antennas 22, 70 and 72. In Fig. 1 the first, second, third and fourth antennas 12, 22, 70 and 72 are positioned one above the other in a coaxial stacked or ganged relationship aligned with the central axis 20 about which the reflector assemblies of antennas 22, 70 and 72 are rotatable. With this configuration each antenna is capable of independently receiving or transmitting a signal at any direction from 0° to 360° relative to the central axis 20. A minor exception to such omnidirective capability is that the vertical waveguide sections 74 feeding the antennas may degrade operation in the direction of the vertical waveguides to some extent. Thus, waveguide sections 74 may comprise three radially stacked waveguides passing upward from antenna 72 to antenna 70, two waveguides passing upward between antennas 70 and 22, and a single waveguide between antennas 22 and 12. Control wiring may also be positioned with the waveguide sections to reach the respective antennas. Waveguide and control wiring couplings are provided within base section 76 (which includes a mounting flange 78) to permit connections to control, receiver and transmitter equipment after the antenna system is mounted upon a vehicle or other support structure. The Fig. 1 configuration permits all of the antennas to be enclosed within a cylindrical radome 80, shown with the front portion cut away. Radome 80 may be a dielectric radome approximately one-half wavelength thick or be of other suitable construction providing protection of the enclosed antennas. In one design of the Fig. 1 form of antenna system for use in an EHF range approaching 60 GHz, the cylindrical radome 80 had an outside diameter of approximately three inches, exclusive of flange 78, and the overall antenna system had a height of about one foot. In this design, the individual reflector assemblies 22, 70 and 72 were effective to provide 3 dB beam coverage of approximately 9 degrees in azimuth and 20 degrees in elevation, at about 56 GHz.

In operation of the Fig. 1 antenna system, the omnidirective antenna 12 can be used as a low gain signal acquisition antenna. Then, when a received signal of interest is identified as lying at a particular direction from the antenna, the reflector assembly of one of the antennas 22, 70 and 72 can be rotated to face in that direction in order to establish a higher gain communication link with the source of such received signal. Correspondingly, the remaining ones of antennas 22, 70 and 72 can be rotated to establish communication links with radio installations at other directions from antenna system 10. It will be appreciated that, with the inclusion of a drive motor as shown in Fig. 2C, the reflector assembly of antenna 22 could simply be caused to rotate slowly while the received signals were monitored until the desired signal (as still being received by antenna 12) was received by antenna 22. Rotation of antenna 22 would be stopped in that position. At short range, such steering could be replaced or augmented by visual sighting of a desired communication antenna and steering of the antenna in the direction so identified. Alternatively, an antenna, such as antenna 12, having a basic omnidirectional pattern can be utilized in a direction finding arrangement for identifying the direction of an incoming signal and automatically directing one of antennas 22, 70 and 72 in such direction. With a simple coaxial type feed as previously discussed, antenna 12 exhibits uniform phase at all azimuth angles. This coverage may be referred to as uniform phase omni or UPO. By implementing a somewhat more complex feed system using prior antenna technology an omni pattern that exhibits a progressive phase characteristic (i.e., 360 degree electrical degree phase change over the 360 degree azimuth coverage) can be provided. This coverage is sometimes referred to as progressive phase omni or PPO. For direction finding purposes during acquisition and direction identification for a LAN network node, a network can be provided to cause both the PPO and UPO omni patterns to be produced at different azimuth portions of a single antenna, such as antenna 12. By properly combining these two patterns, a cardioid pattern is obtained. The angular direction of the resulting cardioid null can be steered by relative phasing of the PPO and UPO patterns. By adjusting the null direction to minimize received signal strength, the direction to the origin of a received signal may be determined. Development of this class of notched omnidirectional antennas by the assignee of the present invention is described in the following article: Koffman and Lopez, "Notched Omnidirectional Antennas", <u>IEEE Transactions on Antennas and Propagation</u>, May 1967, pp.352-6. With adaptation of the feed network of antenna 12 to provide this capability, antenna 12 may be utilized to successively identify a desired signal direction for each of antennas 22, 70 and 72. The resulting directional information can be used in control means 68 to steer the individual antennas to the desired directions, in conjunction with rotational reference information from resolvers 62 indicative of the directional alignment of each individual antenna.

It will be appreciated that the design and configuration of antennas in accordance with the invention enable use of a configuration as in Fig. 1 incorporating one, two, three, or more steerable antenna in combination with one omnidirectional antenna. Alternatively, one or more rotatable antennas may be used alone with manual or other forms of steering.

Referring now to Figs. 3A and 3B, there are shown simplified top and sectional side views of an antenna in accordance with the invention which utilizes a collimator in the form of a dielectric lens in a focusing assembly 22a in substitution for the parabolic pillbox reflector of antenna 22. In Figs. 3A and 3B the lower surface 36 of the pillbox is replaced by a circular ground plane 36a and monopole or probe 32 and sub-reflector 44 may be similar to the like-numbered elements shown in Fig. 2C. The circular choke and elements of the base assembly, which are omitted in Figs. 3A and 3B, may correspond to those shown in Fig. 2C. The principle difference in Figs. 3A and 3B is the omission of the parabolic pillbox configuration and the addition of dielectric lens 80. As indicated by ray path arrows 82, signals radiated from monopole 32 directly, and after reflection from sub-reflector 44, are subjected to a focusing action to provide a directional beam after passage through the lens. Operation of antenna 22a is otherwise similar to that of antenna 22 and lens designs appropriate for particular applications can be provided by persons skilled in the art. With description of the dielectric lens alternative form of antenna, it will be appreciated that other forms of antenna, such as an antenna parabolically shaped in both horizontal and vertical planes (the reflector of Figs. 2A and 2B is flat in the vertical plane), can also be included in antennas in accordance with the invention.

In the embodiment of Fig. 2C, monopole or probe element 32 is supported in fixed position from the wall of waveguide section 46 and extends up through opening 48 in the rotatable reflective section 36. With this arrangement, the fixed probe element remains at the focus of the reflector 28 (which lies on the axis of rotation) even though the reflector assembly is rotated to face in different directions. With reference now to Figs. 4A and 4B, there is illustrated an embodiment in which a different configuration of probe element is supported on the rotatable reflective section 36 so that the probe element 32a rotates with the focusing assembly of the antenna. As shown, the upper portion of probe element 32a is positioned a distance 86 away from the opening 48 which is concentric with the central axis of rotation (axis 20). Probe element 32a, as shown, includes a horizontal portion supported from surface 36 and terminates in a lower probe portion which extends down into the waveguide section 46. Since the lower probe portion lies on the axis of rotation, it will maintain a constant position relative to the waveguide section even as the probe rotates with the reflective section 36. In providing focusing elements such as a sub-reflector and parabolic reflector or dielectric lens, the added flexibility of being able to so position the upper radiating element portion of probe 32a at an offset from the central axis 20 provides added flexibility in overall antenna design. The actual design, shape and offset of radiating element 32a is determined in the particular design and the circular choke and other elements may be provided as described with reference to Fig. 2C.

While there have been described the presently preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications and variations may be made without departing from the invention and it is therefore intended to claim all such modifications and variations as fall within the scope of the invention.

WHAT IS CLAIMED IS:

1. A steerable antenna system comprising:

a first antenna having a wide antenna pattern able to receive signals from a range of directions relative to a central axis;

a second antenna including focusing means rotatable about said central axis and providing a more directive antenna pattern than said first antenna, a circular choke having a movable portion rotatable with said focusing means and a fixed portion cooperating with said movable portion, a transmission line section coupled to said fixed portion of said choke, and coupling means for coupling signals from said reflector to said transmission line section; and

rotation means, coupled to said movable section of said choke, for enabling said focusing means to be rotated toward the direction of a first signal received by said first antenna to permit said second antenna to receive said first signal.

2. A steerable antenna system as in claim 1, additionally comprising:

a third antenna including focusing means, a circular choke having a movable section, a transmission line section, and coupling means as included in said second antenna; and

rotation means, coupled to said movable section of said choke of said third antenna, for enabling said focusing means of said third antenna to be rotated toward the direction of a second signal received by said first antenna to permit said third antenna to receive said second signal.

3. A steerable antenna system as in claim 1, additionally comprising:

steering means, coupled to said movable section of said choke, for rotating said reflector; and

control means, coupled to said steering means and responsive to said first signal, for causing said steering means to rotate said reflector until said first signal is received by said second antenna.

4. A steerable antenna system as in claim 1, wherein said focusing means is a reflector and additionally comprising a sub-reflector positioned in fixed relation to said reflector with said coupling means positioned between said sub-reflector and said reflector.

5. A steerable antenna system as in claim 1, wherein said focusing means is a dielectric lens and additionally comprising a sub-reflector positioned in fixed relation to said dielectric lens with said coupling means positioned between said sub-reflector and said dielectric lens.

6. A steerable antenna system as in claim 1, wherein said second antenna is a pillbox type antenna with a parabolic reflector, said transmission line section is a section of waveguide, and said coupling means is a probe extending through an opening in said movable portion of said choke in alignment with said central axis.

7. A steerable antenna system as in claim 1, wherein said coupling means is a probe extending through an opening in said movable portion of said choke and fixed in position relative to said fixed portion of said choke.

8. A steerable antenna system as in claim 1, wherein said transmission line section is a section of waveguide and said coupling means is rotatable with said focusing means and extends through an opening in said fixed portion of said choke into the center area of said section of waveguide.

9. A steerable antenna system as in claim 1, wherein said first antenna is positioned above said second antenna and said antenna system additionally comprises a cylindrical radome positioned to encompass both of said first and second antennas.

10. A steerable antenna comprising:

a collimator rotatable about a central axis;

a circular choke aligned with said central axis and having a movable portion rotatable with said collimator and a fixed portion cooperating with said movable portion;

a transmission line section aligned with said central axis and coupled to said fixed portion of said choke;

coupling means, including probe means aligned with said central axis, for coupling signals from said collimator to said transmission line section; and

rotation means, coupled to said movable portion of said choke, for enabling said collimator to be rotated for signal reception from a desired direction.

11. A steerable antenna as in claim 10, additionally comprising steering means, coupled to said movable section of said choke, for rotating said collimator for signal reception from said desired direction.

12. A steerable antenna as in claim 10, wherein said collimator is a pillbox type reflector having a focus lying on said central axis and said coupling means is a probe fixed in position relative to said transmission line section and extending to said focus via an opening in said movable portion of said choke.

13. A steerable antenna as in claim 12, additionally comprising a sub-reflector positioned in fixed relation to said reflector on the opposite side of said probe from said reflector.

14. A steerable antenna as in claim 10, wherein said collimator is a parabolic type reflector, said transmission line section is a section of waveguide, and said coupling means includes a first portion fixed in position at the focus of said reflector and a second portion extending through an opening in said fixed portion of said choke and rotatably positioned within said waveguide.

15. A steerable antenna as in claim 10, wherein said collimator is a dielectric lens.

16. A steerable antenna as in claim 10, additionally comprising a radome of cylindrical form

positioned in fixed relation to said fixed position of said choke.

17. A steerable antenna system comprising a plurality of steerable antennas as in claim 10 positioned co-axially in stacked relationship and said reflector of each said antenna being independently rotatable for signal reception from different directions.

18. A steerable antenna system comprising a plurality of steerable antennas as in claim 11 positioned co-axially in stacked relationship and said reflector of each said antenna being independently rotatable for signal reception from different directions.

19. A steerable antenna system as in claim 18, additionally comprising a radome of cylindrical form common to said plurality of steerable antennas.

20. A steerable antenna system comprising a plurality of steerable antennas as in claim 12, positioned co-axially in stacked relationship and said reflector of each said antenna being independently rotatable for signal reception from different directions.

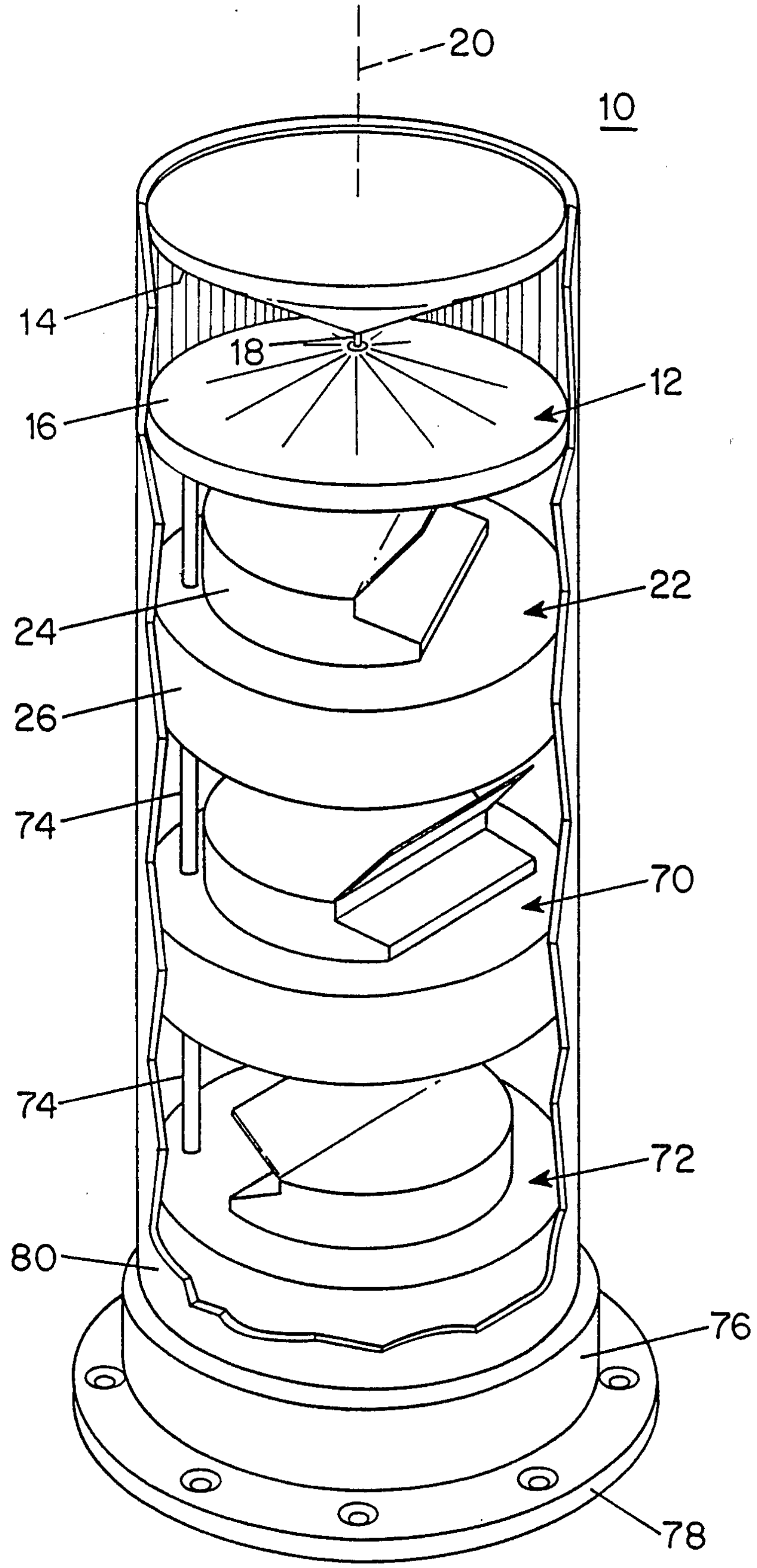

FIG. 1

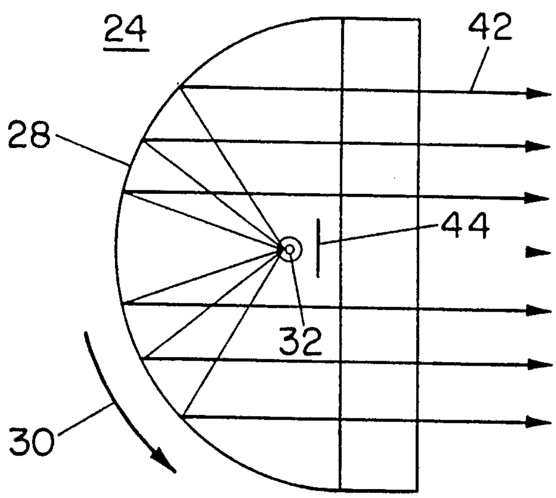

FIG. 2A

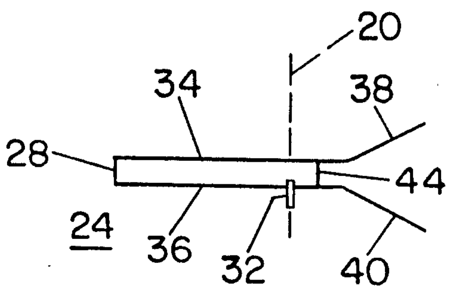

FIG. 2B

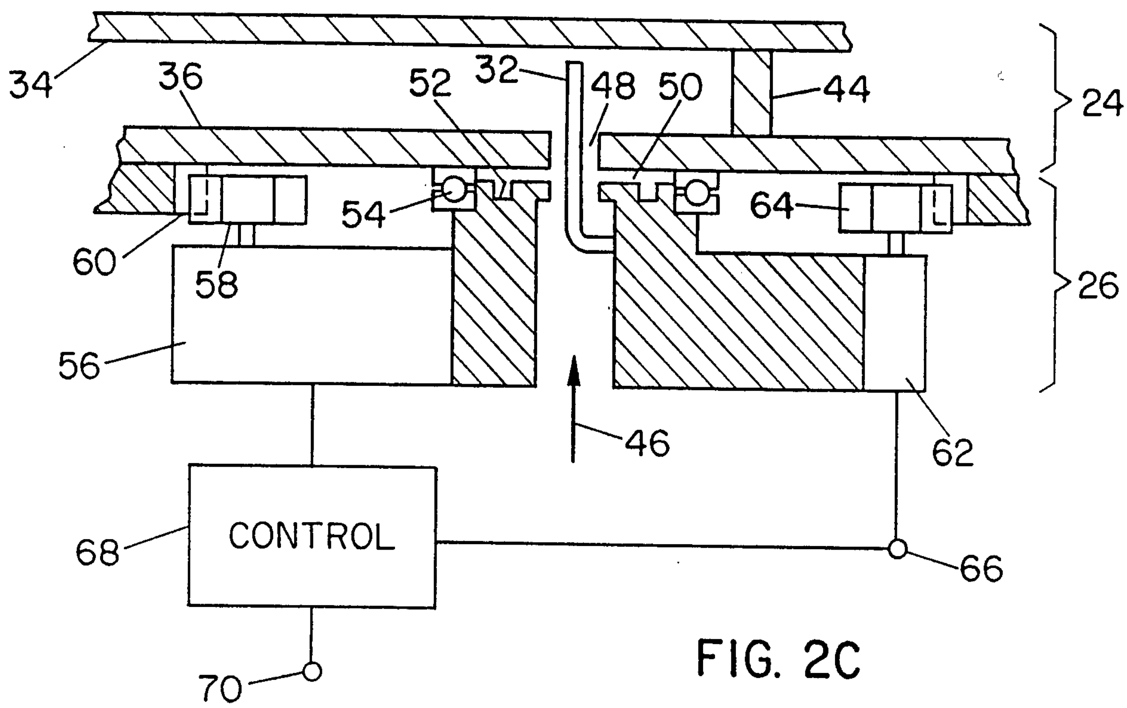

FIG. 2C

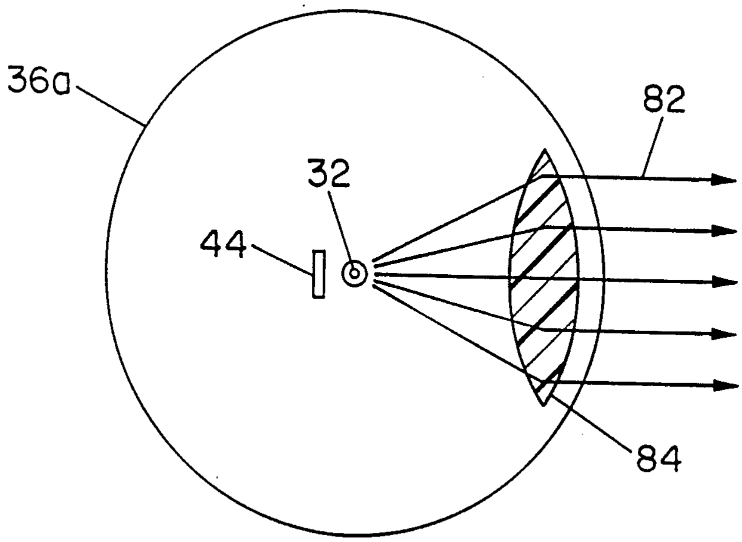

FIG. 3A

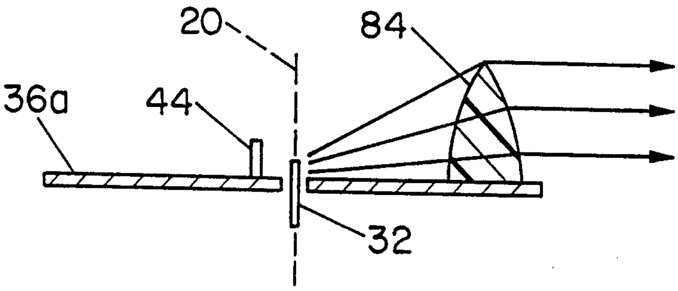

FIG. 3B

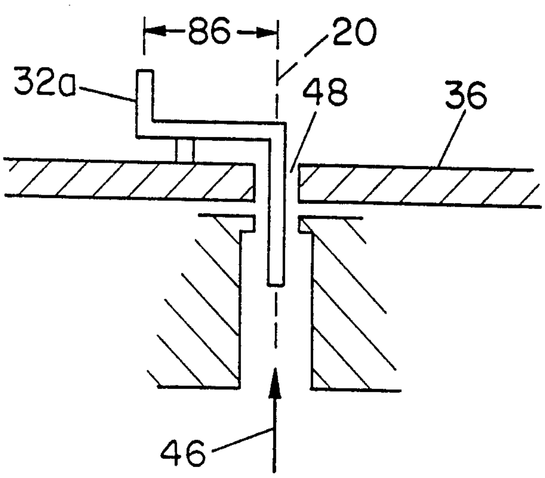

FIG. 4A

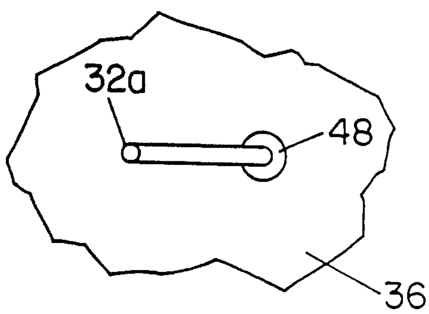

FIG. 4B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 94/04786

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H01Q21/28 H01Q19/13 H01Q13/04 H01Q3/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H01Q G01S G08B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US,A,4 876 554 (TUBBS) 24 October 1989 see column 3, line 1 - column 5, line 41; figures 1-3	10 1
Y	US,A,2 532 551 (JARVIS) 5 December 1950 see claims 1,2; figure 1	1
X A	DE,A,15 16 736 (KRUPP) 2 January 1969 see claims 1-3; figures 1,2	10 2-9, 11-20
A	US,A,3 226 722 (YANG) 28 December 1965 see claims 1-11; figures 1,2	2-20
A	GB,A,1 261 587 (TELEFUNKEN) 26 January 1972 see claims 1-7; figures 1A,B	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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

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Date of the actual completion of the international search	Date of mailing of the international search report
4 August 1994	29.08.94

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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	PATENT ABSTRACTS OF JAPAN vol. 17, no. 609 (P-1640) 9 November 1993 & JP,A,05 188 128 (SUSUMU SAKUMA) 30 July 1993 see abstract -----	1

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