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Judge Robert W. Gettleman
United States District Court

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

ANDREW CORPORATION,	)	
	)	
Plaintiff,	)	
	)	
v.	)	No. 04 C 3594
	)	JURY TRIAL DEMANDED
EMS TECHNOLOGIES, INC.	)	
	)	
Defendant.	)	

FIRST AMENDED COMPLAINT

Plaintiff, ANDREW CORPORATION ("Andrew") for its First Amended Complaint against Defendant, EMS TECHNOLOGIES, INC. (hereafter "EMS") alleges and states:

PARTIES, JURISDICTION AND VENUE

1. Andrew Corporation is a Delaware corporation, with its principal place of business in Orland Park, Cook County, Illinois.

2. EMS Technologies Inc. is a Georgia corporation with its principal place of business in Norcross, Georgia.

3. This is a complaint for patent infringement pursuant to 35 U.S.C. § 271 *et seq.* This court has subject matter jurisdiction over Andrew's claims pursuant to 28 U.S.C. § 1331 and 1338.

4. EMS is doing business within this judicial district, subjecting it to jurisdiction within the judicial district and making venue proper in this district pursuant to 28 U.S.C. §§ 1391 and 1400.

ANDREW'S PATENTS

5. On May 20, 2003 United States Patent No. 6,567,051 ("the '051 patent") entitled "Antenna Control System," was duly and legally issued to William Emil Heinz and Mathea Martin Ernest Ehlen and assigned to Andrew Corporation. A true and correct copy is attached as Exhibit A.

6. On June 3, 2003, United States Patent No. 6,573,875 ("the '875 patent"), entitled "Antenna System," was duly and legally issued to Martin L. Zimmerman, Jamie Paske, Jim Giacobazzi, and Kevin E. Linehan and assigned to Andrew Corporation. A true and correct copy is attached as Exhibit B.

7. On July 8, 2003, United States Patent No. 6,590,546 ("the '546 patent") entitled "Antenna Control System" was duly and legally issued to William Emil Heinz and Mathias Martin Ernest Ehlen and assigned to Andrew Corporation. A true and correct copy is attached as Exhibit C.

8. On July 29, 2003, United States Patent 6,600,457 ("the '457 patent") entitled "Antenna Control System" was duly and legally issued to William Emil Heinz and Mathias Ernest Ehlen and assigned to Andrew Corporation. A true and correct copy is attached as Exhibit D.

DEFENDANT'S INFRINGEMENT

9. EMS has been and still is infringing the '051, '875, '546 and '457 patents by importing, making, selling, using or offering to sell devices embodying the patented inventions or inducing or contributing to the infringement by others of the '051, '875, '546 and '457 patents, and will continue to do so unless enjoined by this Court.

10. EMS has been, and still is infringing, at least claims 37-39, 41-42, 55 and 56 of Andrew's '051 patent by importing, making, selling, using, or offering to sell devices embodying the patented inventions, including EMS's COBRA antenna and antenna control devices, including models RR65-19-VDP; RR65-18-VDPL2; RR65-17-VDPL2; RR90-18-VDP; RR90-17-VDPL2; DR65-19-VDPQ; DR65-18-VDPL2Q; DR85-17-VDPL2Q; MB48RR-65-VDPBL; MB48RR-80-VDPBL; and MB72RR-80-VDPBL. EMS is also inducing or contributing to the infringement by others of the '051 patent, including claims 37-39, 41-42, 55 and 56, by selling or offering to sell to third parties, with the intent to induce infringement, the COBRA antenna and antenna control devices listed above. Further, the COBRA antenna and antenna control devices listed above are not suitable for substantial non-infringing use.

11. EMS has been, and still is infringing, at least claims 1, 3, 13-16, 30, 44-46, 54-56, and 62-69 of Andrew's '457 patent by importing, making, selling, using, or offering to sell devices embodying the patented inventions, including EMS's COBRA antenna and antenna control devices, including models MB48RR-65-VDPBL; MB48RR-80-VDPBL; and MB72RR-80-VDPBL. EMS is also inducing or contributing to the infringement by others of the '457 patent, including claims 1, 3, 13-16, 30, 44-46, 54-56, and 62-69, by selling or offering to sell to third parties, with the intent to induce infringement, the COBRA antenna and antenna control devices listed above. Further, the COBRA antenna and antenna control devices listed above are not suitable for substantial non-infringing use.

12. EMS has been, and still is infringing, at least claims 1, 3, 11-12, 39 and 50 of Andrew's '546 patent by importing, making, selling, using, or offering to sell devices embodying the patented inventions, including EMS's COBRA antenna models, including models RR65-19-VDP; RR65-18-VDPL2; RR65-17-VDPL2; RR90-18-VDP; RR90-17-VDPL2; DR65-19-VDPQ; DR65-18-VDPL2Q; DR85-17-VDPL2Q; MB48RR-65-VDPBL; MB48RR-80-VDPBL; and MB72RR-80-VDPBL. EMS is also inducing or contributing to the infringement by others of the '546 patent, including claims 1, 3, 11-12, 39 and 50, by selling or offering to sell to third parties, with the intent to induce infringement, the COBRA antenna and antenna control devices listed above. Further, the COBRA antenna and antenna control devices listed above are not suitable for substantial non-infringing use.

13. EMS has been, and still is infringing, at least claim 51 of Andrew's '875 patent by importing, making, selling, using, or offering to sell devices embodying the patented inventions, including EMS's COBRA antenna models, including models RR65-19-VDP; RR65-18-VDPL2; RR65-17-VDPL2; RR90-18-VDP; RR90-17-VDPL2; DR65-19-VDPQ; DR65-18-VDPL2Q; DR85-17-VDPL2Q; MB48RR-65-VDPBL; MB48RR-80-VDPBL; and MB72RR-80-VDPBL. EMS is also inducing or contributing to the infringement by others of the '875 patent, including claim 51, by selling or offering to sell to third parties, with the intent to induce infringement, the COBRA antenna and antenna control devices listed above. Further, the COBRA antenna and antenna control devices listed above are not suitable for substantial non-infringing use.

THE HARM TO ANDREW

14. EMS, by its infringing conduct and its inducement of infringement by others, has caused Andrew irreparable harm for which there is no adequate remedy at law.

15. EMS has engaged in its conduct wilfully and in complete disregard of, or with indifference to, Andrew's rights and interests.

16. Andrew has suffered damage as a result of defendant's infringement to date.

17. This is an exceptional case as that term is defined in 35 U.S.C. §285.

WHEREFORE, Andrew prays that this Court:

1. Preliminarily and permanently enjoin EMS and its officers, agents, servants, employees and attorneys and those in active concert or participation with them, who receive actual notice of the Order, from importing, manufacturing, using, selling and/or offering for sale, devices which infringe the '051, '875, '546 or '457 patents.

2. Issue an order directing EMS and its officers, agents, servants, employees and attorneys and those in active concert or participation with them who receive actual notice of the Order, to destroy all molds, machines, tooling or other equipment used in the manufacture of items infringing the '051, '875, '546 or '457 patents.

3. Award Andrew monetary damages adequate to compensate Andrew for past infringement consistent with 35 U.S.C. § 284, up to and including treble the amount of actual damages assessed, together with costs and prejudgment interest.

4. Award Andrew its reasonable attorneys' fees pursuant to 35 U.S.C. § 285.

5. Grant and award any and all relief found necessary and proper under these circumstances.

JURY DEMAND

Andrew requests a trial by jury on its claims.

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(12) **United States Patent**
Heinz et al.

(10) **Patent No.: US 6,567,051 B2**
(45) **Date of Patent: May 20, 2003**

(54) ANTENNA CONTROL SYSTEM

(75) Inventors: **William Emil Heinz**, Wellington (NZ); **Mathias Martin Ernest Ehlen**, Wellington (NZ)

(73) Assignee: **Andrew Corporation**, Orland Park, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/073,806**

(22) Filed: **Feb. 11, 2002**

(65) **Prior Publication Data**

US 2002/0135530 A1 Sep. 26, 2002

Related U.S. Application Data

(63) Continuation of application No. 09/713,614, filed on Nov. 15, 2000, now Pat. No. 6,346,924, which is a continuation of application No. 08/817,445, filed as application No. PCT/NZ95/00106 on Oct. 16, 1995, now Pat. No. 6,198,458.

(30) **Foreign Application Priority Data**

Nov. 4, 1994 (NZ) 264864
Aug. 15, 1995 (NZ) 272778

(51) **Int. Cl.**[7] **H01Q 3/00**
(52) **U.S. Cl.** **343/757; 343/766; 343/853**
(58) **Field of Search** 343/757, 763, 343/765, 766, 758, 853

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Primary Examiner—Don Wong
Assistant Examiner—Hoang Nguyen
(74) *Attorney, Agent, or Firm*—Welsh & Katz, Ltd.

(57) **ABSTRACT**

An antenna control system enabling the remote variation of antenna beam tilt. A drive means continuously adjusts phase shifters of a feed distribution network to radiating elements to continuously vary antenna beam tilt. A controller enables the beam tilt of a number of antenna at a site to be remotely varied.

56 Claims, 8 Drawing Sheets

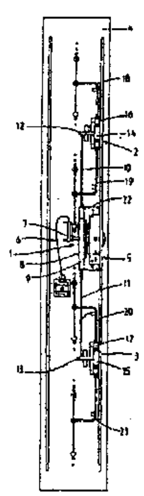

EXHIBIT
A

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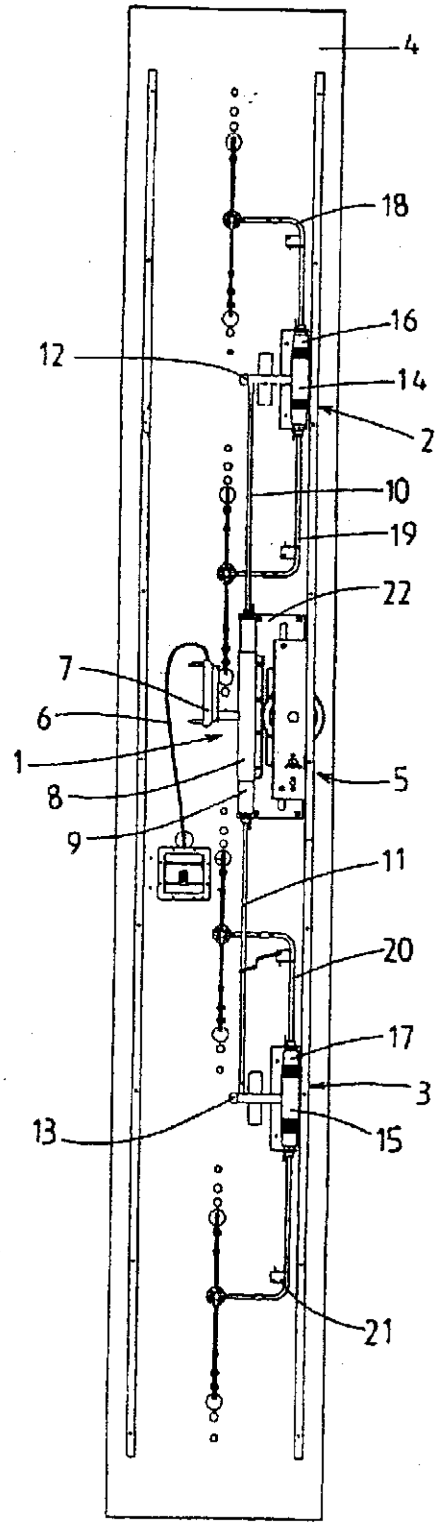

FIG.1

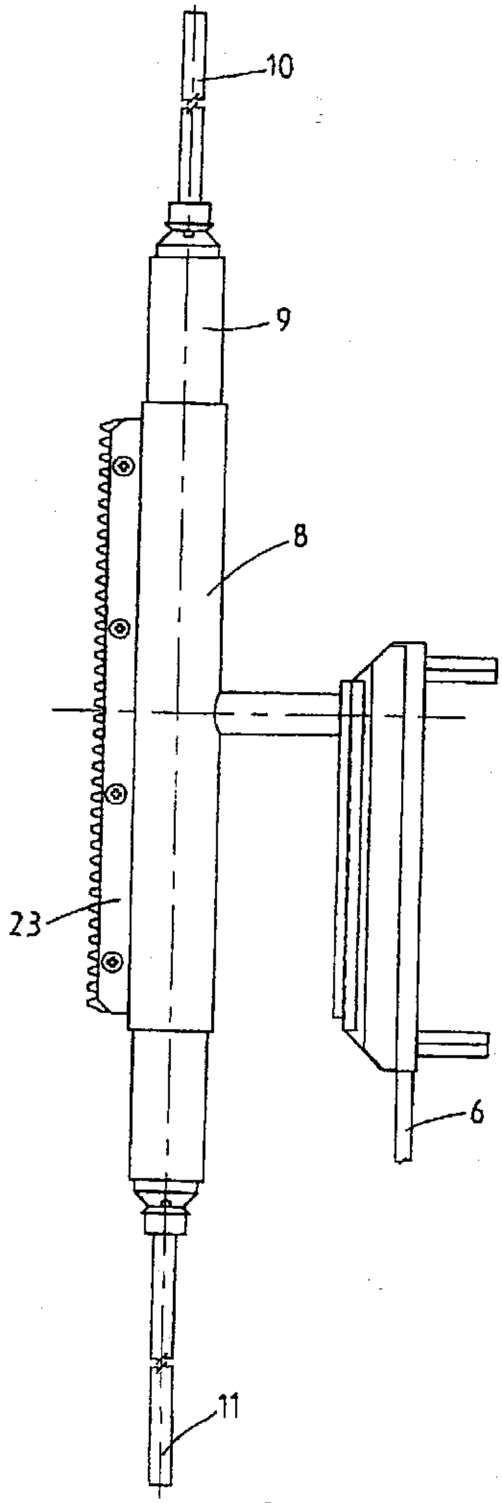

FIG. 2

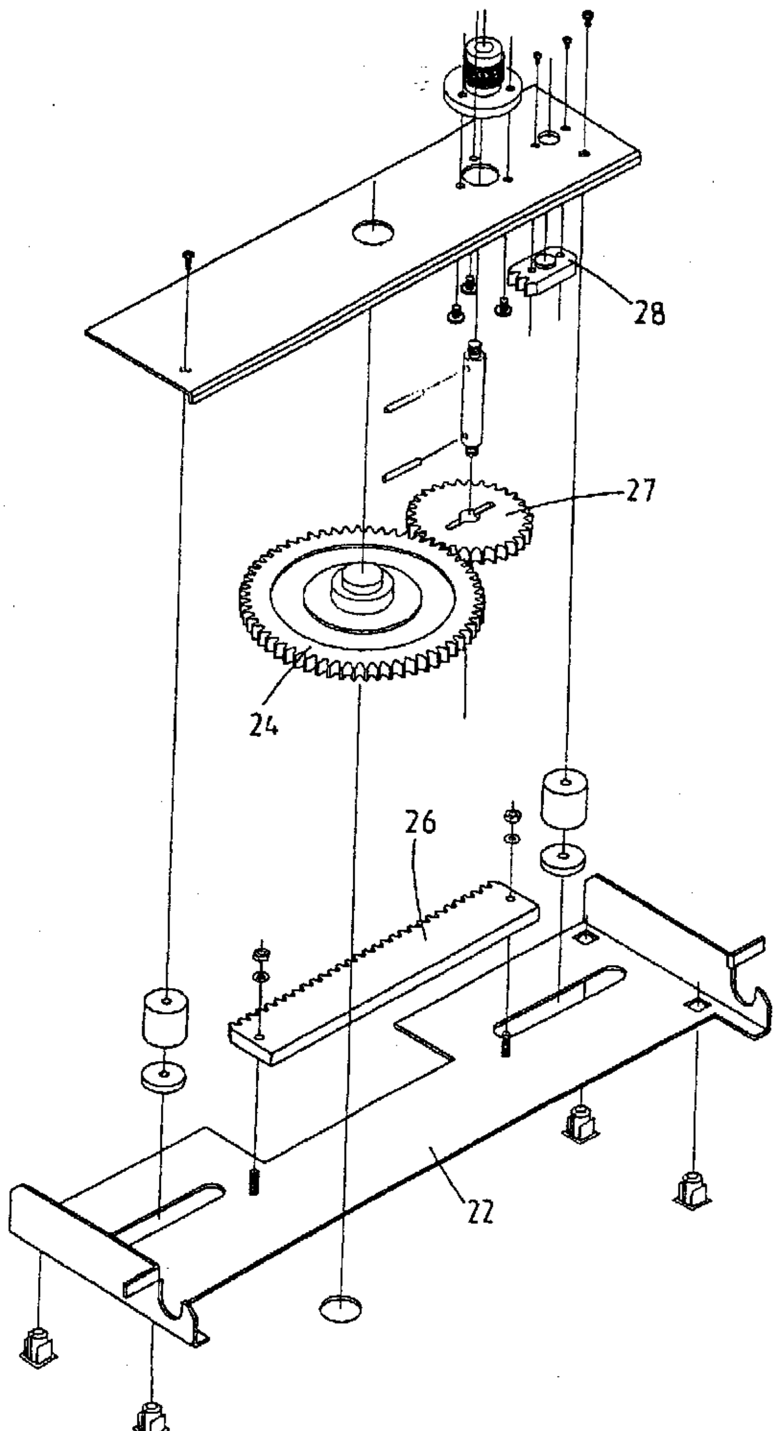

FIG. 3

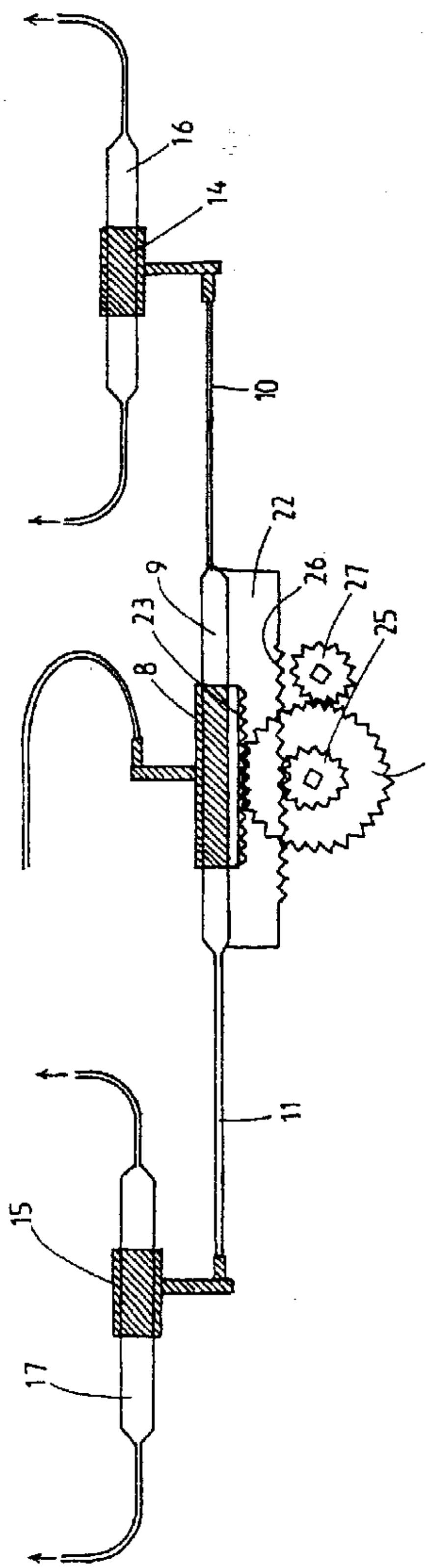

FIG. 4

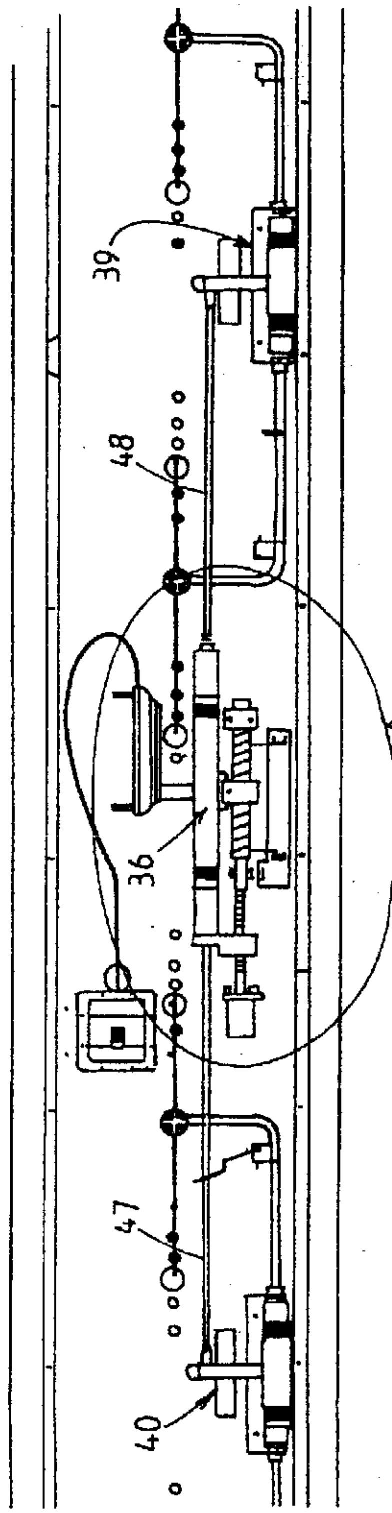

FIG. 5

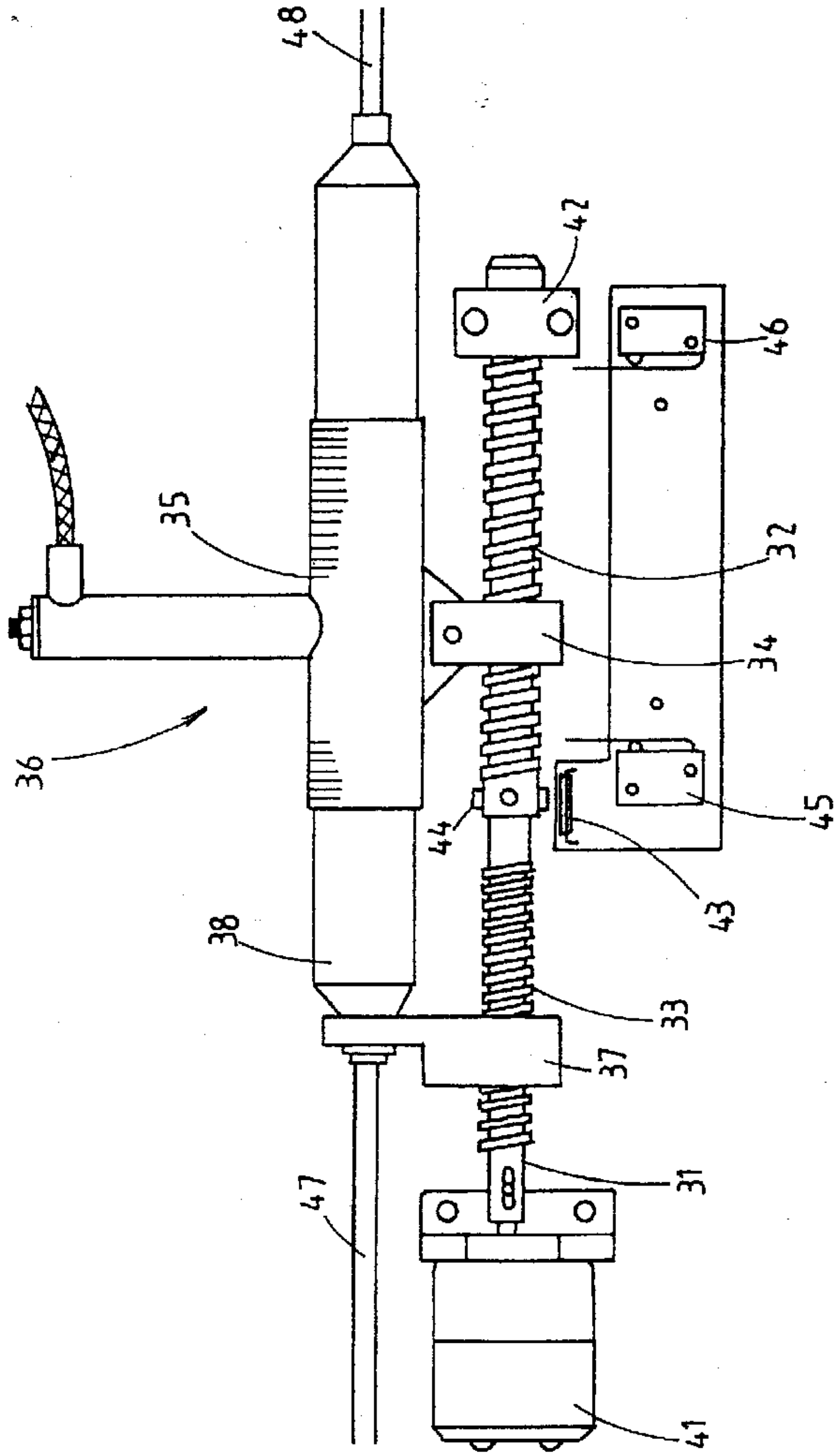

FIG.6

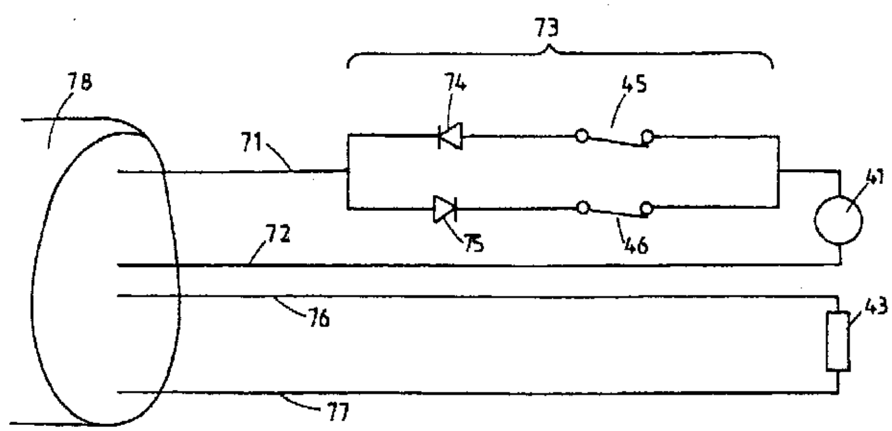

FIG. 7

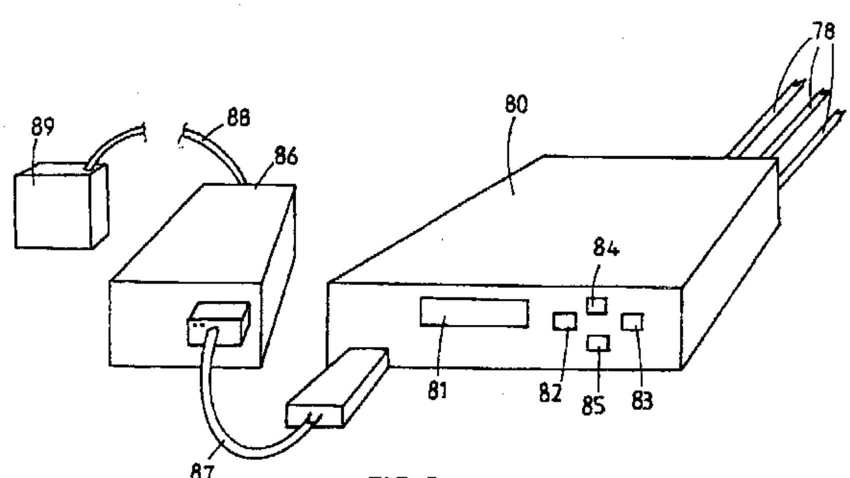

FIG. 8

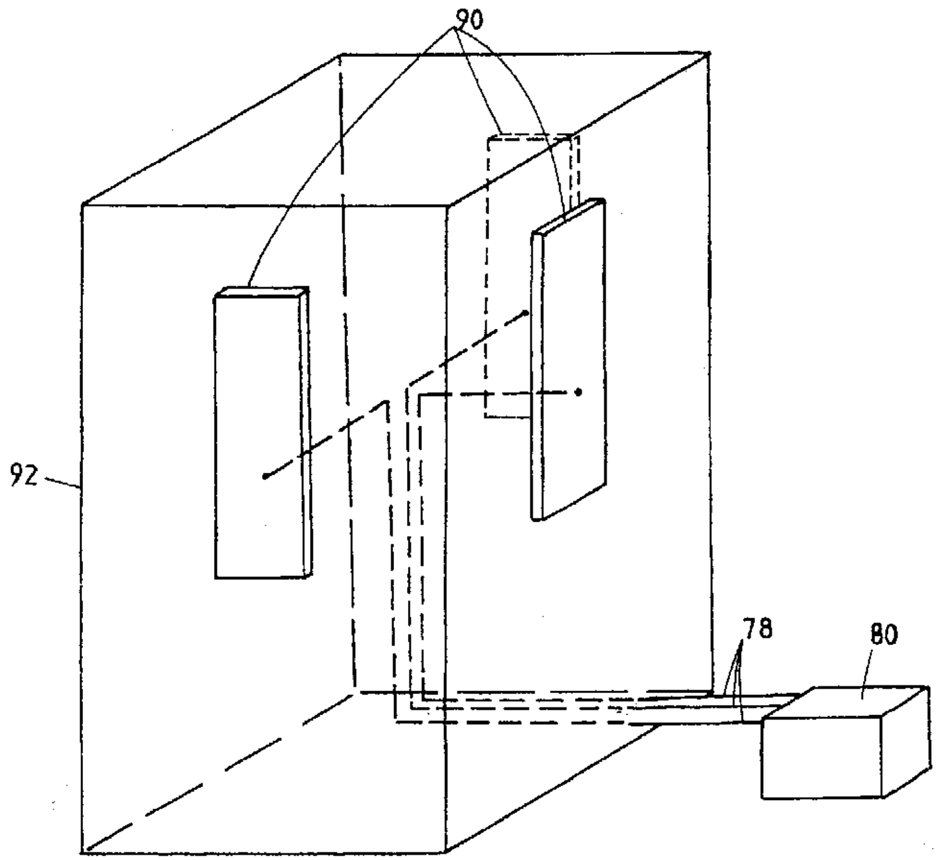

FIG. 9

ANTENNA CONTROL SYSTEM

This is a continuation of application Ser. No. 09/713,614, filed Nov. 15, 2000, entitled Antenna Control System, now U.S. Pat. No. 6,346,924, which is a continuation of application Ser. No. 08/817,445, filed Oct. 16, 1995, entitled Antenna Control System, now U.S. Pat. No. 6,198,458 B1, which is a 371 of PCT/NZ95/00106, filed Oct. 16, 1995.

THE TECHNICAL FIELD

The present invention relates to an antenna control system for varying the beam tilt of one or more antenna. More particularly, although not exclusively, the present invention relates to a drive system for use in an antenna which incorporates one or more phase shifter.

BACKGROUND OF THE INVENTION

In order to produce downtilt in the beam produced by an antenna array (for example a panel antenna) it is possible to either mechanically tilt the panel antenna or electrically steer the beam radiated from the panel antenna according to techniques known in the art.

Panel antennas, such as those to which the present application is concerned, are often located on the sides of buildings or similar structures. Mechanical tilting of the antenna away from the side of the building increases the susceptibility of the installation to wind induced vibration and can impact on the visual environment in situations where significant amounts of downtilt are required.

In order to avoid the above difficulties, electrical beam steering can be effected by introducing phase delays into the signal input into radiating elements or groups of radiating elements in an antenna array. Such techniques are described in New Zealand Patent Specification No. 235010.

Various phase delay techniques are known, including inserting variable length delay lines into the network feeding to the radiating element or elements, or using PIN diodes to vary the phase of a signal transmitted through the feeder network.

A further means for varying the phase of two signals is described in PCT/NZ94/00107 whose disclosure is incorporated herein by reference. This specification describes a mechanically operated variable differential phase shifter incorporating one input and two outputs.

For the present purposes it is sufficient to note that phase shifters such as those described in PCT/NZ94/00107 are adjusted mechanically by sliding an external sleeve along the body of the phase shifter which alters the relative phase of the signals at the phase shifter outputs.

A typical panel antenna will incorporate one or more phase shifters and the present particular embodiment includes three phase shifters. A signal is input to the primary phase shifter which splits the signal into two signals having a desired phase relationship. Each phase shifted signal is then input into a secondary phase shifter whose outputs feeds at least one radiating element. In this manner a progressive phase shift can be achieved across the entire radiating element array, thus providing a means for electrically adjusting the downtilt of the radiated beam. Other phase distributions are possible depending on the application and shape of the radiated beam.

While the steering action is discussed in the context of downtilt of the radiated beam, it is to be understood that the present detailed description is not limited to such a direction. Beam tilt may be produced in any desired direction.

Another particular feature of the variable differential phase shifters is that they provide a continuous phase adjustment, in contrast with the more conventional stepped phase adjustments normally found in PIN diode or stepped length delay line phase shifters.

In a panel antenna of the type presently under consideration, it is desirable to adjust the entire phase shifter array simultaneously so that a desired degree of beam tilt may be set by the adjustment of a single mechanical setting means. The mechanical drive which performs such an adjustment must result in reproducible downtilt angles and be able to be adapted to provide for a number of different phase shifter array configurations.

It is also desirable that the beam tilt of an antenna may be varied remotely to avoid the need for personnel to climb a structure to adjust antenna beam tilt.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a mechanical drive system for use in adjusting mechanical phase shifters which mitigates the abovementioned difficulties, provides a solution to the design requirements of the antennas or antenna arrays described above, or at least provides the public with a useful choice.

Accordingly, there is provided a mechanical adjustment means for adjusting the relative phase shifts produced by a plurality of phase shifters connected to an array of radiating elements, said mechanical adjustment means including:

first means for moving a first portion of a first phase shifter relative to a second portion of said first phase shifter to vary the phase difference between output signals from the first phase shifter; and

second means for moving a first portion of a second phase shifter relative to a second portion of said second phase shifter to vary the phase difference between output signals from the second phase shifter, wherein the second phase shifter is fed from an output of the first phase shifter and the degree of movement of the second means is dependent upon the degree of movement of the first means.

Preferably, movement of the second means results in simultaneous movement of a first portion of a third phase shifter with respect to a second portion of the third phase shifter wherein the third phase shifter is fed from an output of the first phase shifter.

Preferably the outputs of the second and third phase shifters are connected to radiating elements so as to produce a beam which tilts as the first and second means adjusts the phase shifters.

Preferably the movement of the first portion of the first phase shifter a first distance relative to the second portion of the first phase shifter results in relative movement between first portions of the second and third phase shifters relative to second portions of the second and third phase shifters of about twice the first distance.

According to a first preferred embodiment the first means includes a gear wheel which drives a rack connected to a first portion of the first phase shifter, arranged so that rotation of the first gear wheel causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter. Preferably, the second portion of the first phase shifter is mounted to a carriage and the outputs of the first phase shifter are connected to inputs of the second and third phase shifters by push rods so that movement of the second portion of the first phase shifter moves the first portions of the second and third phase shifters with respect to the second portions of the second and third phase shifters.

Preferably a second gear is provided co-axial with and connected to a shaft driving the first gear which drives a rack connected to the second part of the first phase shifter so that rotation of the second gear causes movement of the first portion of the second and third phase shifters relative to the second portions of the second and third phase shifters.

Preferably the ratio between the first and second gear wheels is about 3:1.

According to a second embodiment of the present invention the adjustment means includes a shaft and said first means includes a first threaded portion provided on said shaft and a first cooperating threaded member connected to the first portion of the first phase shifter. The second means includes a second threaded portion provided on said shaft and a second cooperating threaded member connected to the first portion of the second phase shifter. The arrangement is such that rotation of the shaft causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter at a rate of about twice that of the movement of the first portion of the second phase shifter relative to the second portion of the second phase shifter.

Preferably the second threaded member is connected to the second portion of the first phase shifter and moves the first portion of the second phase shifter via a push rod. This push rod is preferably a coaxial line connecting an output from the first phase shifter to the input to the second phase shifter.,

Preferably there is further provided a third phase shifter fed from a second output of the first phase shifter via a push rod which moves a first portion of the third phase shifter in unison with the first portion of the second phase shifter.

According to a further aspect of the invention there is provided an antenna system comprising one or more antenna including electromechanical means for varying the downtilt of the antenna and a controller, external to the antenna, for supplying drive signals to the electromechanical means for adjusting downtilt.

Preferably the system includes a plurality of antennas and the controller may adjust the downtilt for the plurality of antennas and store the degree of downtilt of each antenna in memory.

Preferably the controller may be controlled remotely from a control centre so that a plurality of such systems may be remotely controlled as part of a control strategy for a number of cellular base stations.

Preferably the electromechanical means varies the electrical downtilt of each antenna and means are included for monitoring the electromechanical means and providing signals representative of the position of the electromechanical means to the controller.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1: shows a panel antenna incorporating a phase shifter drive mechanism according to a first embodiment of the invention.

FIG. 2: illustrates a primary phase shifter incorporating a gear rack.

FIG. 3: illustrates an exploded view of the adjustment assembly incorporated into the carriage.

FIG. 4: shows diagrammatically the operation of the drive mechanism according to the first embodiment.

FIG. 5: shows a panel antenna incorporating a phase shifter drive mechanism according to a second embodiment of the invention.

FIG. 6: shows the phase shifter drive mechanism of FIG. 5 in detail.

FIG. 7: shows the electrical connection of the motor, switches and reed switch of the drive mechanism shown in FIG. 6.

FIG. 8: shows a controller for controlling the drive mechanism shown in FIGS. 6 and 7.

FIG. 9 shows an antenna system according to one aspect of the present invention having a plurality of antennas controlled by a controller.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to FIG. 1 there is shown the back side of a panel antenna 4 having a first phase shifter 1, a second phase shifter 2, a third phase shifter 3 and a phase shifter drive mechanism 5. Feed line 6 is connected to input 7 of phase shifter 1. A first portion 8 of phase shifter 1 is moveable relative to a second portion 9 of phase shifter 1.

Output signals from phase shifter 1 are supplied via lines 10 and 11 to inputs 12 and 13 of phase shifters 2 and 3 respectively. Feed lines 10 and 11 comprise coaxial push rods which serve the functions both of feeding signals from the outputs of phase shifter 1 to phase shifters 2 and 3 and moving first portions 14 and 15 of phase shifters 2 and 3 relative to second portion 16 and 17 of phase shifters 2 and 3 respectively.

Signals output from phase shifters 2 and 3 are supplied via coaxial lines 18, 19, 20 and 21 to be fed to respective radiating elements (not shown).

In use first portion 8 of phase shifter 1 may be moved relative to second portion 9 of phase shifter 1 to change the relative phase of signals supplied via lines 10 and 11 to phase shifters 2 and 3 respectively. First portions 14 and 15 of phase shifters 2 and 3 may be moved relative to second portions 16 and 17 of phase shifters 2 and 3 to vary the phase of signals supplied by lines 18, 19, 20 and 21 to respective radiating elements.

When phase shifters 1, 2 and 3 are adjusted in the correct respective portions the beam emitted by the antenna can be tilted as required. It will be appreciated that where a less defined beam is required fewer phase shifters may be employed.

To achieve even continuous beam tilting for the embodiment shown in FIG. 1 the first portions 14 and 15 of phase shifters 2 and 3 should move relative to the second portion 16 and 17 of phase shifters 2 and 3 at the same rate. The first portion 8 of phase shifter 1 must however move relative to the second portion 9 of phase shifter 1 at twice this rate. In the arrangement shown second portion 9 of phase shifter 1 is connected to carriage 22. Movement of carriage 22 results in movement of first portions 14 and 15 of phase shifters 2 and 3 via push rods 10 and 11.

Referring now to FIG. 4, operation of the phase shifter drive mechanism will be explained. Second portion 9 of phase shifter 1 is mounted to a carriage 22 which can move left and right. If carriage 22 is moved to the left first portions 14 and 15 of phase shifters 2 and 3 will be moved to the left via push rods 10 and 11. First portion 8 of phase shifter 1 may be moved relative to second portion 9 of phase shifter 1 to vary the phase of signal supplied to phase shifters 2 and 3.

According to this first embodiment a rack 23 is secured to first portion 8 of phase shifter 1. Upon rotation of gear wheel 24 first portion 8 of phase shifter 1 may be moved to the left or the right. A smaller gear wheel **25** is secured to and rotates with gear wheel **24**. This gear wheel engages with a rack **26** provided on carriage **22**. A further gear wheel **27** is provided which may be driven to rotate gear wheels **24** and **25** simultaneously.

Gear wheel **24** has 90 teeth whereas gear wheel **25** has 30 teeth. It will therefore be appreciated that rotation of gear wheel **24** results in first portion **8** of phase shifter **1** being moved three times as far as carriage **22** (and hence first portions **14** and **15** of phase shifters **2** and **3**). However, as carriage **22** is moving in the same direction as the first portion **8** of phase shifter **1** it will be appreciated that the relative movement between first portion **8** and second portion **9** of phase shifter **1** is twice that of the relative movement between the first and second portions of phase shifters **2** and **3**. Accordingly, this arrangement results in the relative phase shift produced by phase shifter **1** being twice that produced by phase shifters **2** and **3** (as required to produce even beam tilting in a branched feed arrangement).

The particular arrangement is shown in more detail in FIGS. **2** to **4**. It will be appreciated that gear wheel **27** may be driven by any appropriate manual or driven means. Gear wheel **27** may be adjusted by a knob, lever, stepper motor or other driven actuator. A keeper **28** may be secured in place to prevent movement once the desired settings of the phase shifters have been achieved.

Referring now to FIGS. **5** and **6**, a second embodiment will be described. As seen in FIG. **5**, the arrangement is substantially the same as that shown in the first embodiment except for the drive mechanism **30** employed, which is shown in FIG. **6**.

In this embodiment the drive mechanism includes a shaft **31** having a first threaded portion **32** and a second threaded portion **33** provided thereon. A first threaded member **34** is connected to a first portion **35** of primary phase shifter **36**. A second threaded member **37** is connected to the second portion **38** of primary phase shifter **36**.

First threaded portion **32** is of three times the pitch of second threaded portion **33** (e.g. the pitch of the first threaded portion **32** is 6 mm whereas the pitch of the second threaded portion is 2 mm). In this way, first portion **35** is driven in the direction of movement at three times that of second portion **38**. In this way the phase shift produced by primary phase shifter **36** is twice that of second and third phase shifters **39** and **40**.

Shaft **31** is rotated by motor **41**. This may suitably be a geared down 12 volt DC motor. The other end of shaft **31** is supported by end bearing **42**. A reed switch **43** is provided to detect when magnets **44** pass thereby. In this way the number of rotations of shaft **31** may be monitored. Limit switches **45** and **46** may be provided so that the motor is prevented from further driving shaft **31** in a given direction if threaded member **34** abuts a lever of limit switch **45** or **46** respectively.

Operation of the drive means according to the second embodiment will now be described by way of example. Motor **41** may rotate shaft **31** in an anticlockwise direction, viewed from right to left along shaft **31**. Threaded member **37** is driven by second threaded portion **33** to move push rods **47** and **48** to the left, and thus to adjust phase shifters **39** and **40**.

Threaded member **34** is driven to the left at three times the rate of threaded member **37**. First portion **35** thus moves to the left at three times the rate of second portion **38**. First portion **35** therefore moves relative to second portion **38** at twice the speed the first portions of phase shifters **39** and **40**

move relative to their respective second portions. In this way, delays are introduced in the paths to respective radiating elements so as to produce an evenly tilting beam.

The conductivity of reed switch **43** is monitored so that the number of rotations, or part rotations, of shaft **31** may be monitored. If the motor continues driving shaft **31** until threaded member **34** abuts the lever of limit switch **45** then logic circuitry will only permit motor **41** to drive in the opposite direction. Likewise if threaded member **34** abuts the lever of limit switch **46** the motor **41** will only be permitted to drive in the opposite direction.

It will be appreciated that the techniques of both embodiments could be employed in antenna arrays using a larger number of phase shifters. In such applications the relative movement of the first portion of each phase shifter relative to the second portion of each phase shifter would decreased by a factor of 2 for each successive phase shifter along each branch. The ratios used may be varied if the radiation pattern of the antenna needs to be altered to account for the directivity of the individual radiating elements and the effect of the back panel as the amount of downtilt is varied.

Components of the drive mechanism **30** are preferably formed of plastics, where possible, to reduce intermodulation. Threaded members **34** and **37** preferably include plastic links to phase shifter **36** to reduce intermodulation.

It will be appreciated that a number of mechanical drive arrangements may be used to achieve adjustment of the phase shifters in the desired ratio. It is also to be appreciated that sophisticated control electronics may be employed, although the simplicity of construction of the present invention is seen as an advantage.

FIG. **7** shows how motor **41**, reed switch **43** and switches **45** and **46** are connected to lines **71**, **72**, **76** and **77** from an external controller. Lines **71**, **72**, **76** and **77** are sheathed by conduit **78**. Lines **71** and **72** supply current to drive motor **41**. Section **73** ensures that if threaded member **34** is driven to either the left-hand side limit or the right-hand side limit it can only be driven in the opposite direction. In the position shown in FIG. **7**, switch **45** directly connects line **71** to switch **46** via diode **74**. In the position shown switch **46** connects line **71** to motor **41** via diode **75**. This is the normal position of the switches when threaded member **34** is not at either extreme limit. When threaded member **34** is driven to the extreme left, for example, and actuates switch **45**, then switch **45** open circuits the path via diode **74**. Diode **74** allows current flow in the direction allowing motor **41** to drive to the left. Accordingly, when switch **45** is open, motor **41** can only drive in such a direction as to drive threaded member **34** to the right (i.e.: current in the direction allowed by diode **75**).

Likewise, if threaded member **34** is driven to the extreme right, switch **46** is opened to break the path via diode **75**. This prevents motor **41** driving in such a direction as to drive threaded member **34** further to the right.

Lines **76** and **77** are connected to reed switch **43** so that the opening and closing of reed switch **43** may be monitored by an external control unit. In use, the opening and closing of reed switch **43** may be monitored to determine the position of threaded member **34**, and hence the corresponding degree of tilt of the antenna.

To select an initial angle of downtilt threaded member **34** may be driven to the extreme right. An external controller may provide a current in one direction to motor **41** to drive member **34** to the right. The motor will continue to be driven to the right until threaded portion **34** abuts switch **46**. When switch **46** is opened diode **75** will be open circuited, which will prevent the motor being driven further to the right.

The controller will sense that threaded member 34 is at its extreme right position as it will detect that reed switch 43 is not opening and closing. After a predetermined delay the controller may then provide a current in the opposite direction via lines 71 and 72 to motor 41 to drive it to the left. As the motor is driven to the left the controller will monitor the opening and closing of reed switch 43 to determine how far threaded member 34 has moved to the left. The controller will continue to move threaded member 34 to the left until reed switch 43 has opened and closed a predetermined number of times, corresponding to a desired angle of downtilt. Alternatively, threaded member 34 may be driven to the extreme left and then back to the right.

As shown in FIG. 9, at an antenna site a number of such panels 90 may be installed and controlled by a single controller 80 as shown in FIG. 8. The four wires 71, 72, 76, and 77 correspond to respective cable groups 78 to three such antenna panels. Controller 80 may be provided at the base of an antenna site to allow an operator to adjust the tilt of a plurality of antennas at ground level, rather than requiring a serviceman to climb up the antenna structure 92 and adjust each antenna manually. Alternatively, controller 80 may be a hand-held unit which can be plugged into a connector at the base of an antenna to adjust the antenna at a site.

Controller 80 may include a display 81, an "escape" button 82, an "enter" button 83, an "up" button 84 and "down" button 85. At power up display 81 may simply display a home menu such as "Deltec NZ Ltd© 1995". Upon pressing any key, a base menu may be displayed including options such as:

unlock controls
set array tilt
measure tilt
enable array
disable array
lock controls

The up/down keys may be used to move through the menu and the enter key 83 used to select an option. If "unlock controls" is selected a user will then be required to enter a three digit code. The up/down keys may be used to move through the numbers 0 to 9 and enter used to select each number. If the correct code is entered "locked released" appears. If the incorrect code is entered "controls locked" appears and a user is returned to the home menu. If "set array tilt" is selected from the base menu the following may appear:

set array tilt
array: 01 X.X°

The up-down keys 84, 85 may be used to select the desired array number. The enter key accepts the selected array and the previously recorded angle of downtilt may be displayed as follows:

set array tilt
array: 01 4.6°

In this example the previously set angle of downtilt with 4.6°. Using the up/down keys 84,85 a new angle may be entered. Controller 80 may then provide a current to motor 41 via lines 71 and 72 to drive threaded portion 34 in the desired direction to alter the downtilt. The opening and closing of reed switch 43 is monitored so that threaded member 34 is moved in the desired direction for a predetermined number of pulses from reed switch 43. The downtilt for any other array may be changed in the same manner. If the controller is locked a user may view an angle of downtilt but will not be able to alter the angle.

If the "measure array" option is selected the present angle of downtilt of the antenna may be determined. Upon selecting the "measure tilt" function from the base menu, the following display appears:

measure tilt
array: 01 X.X°

The up/down buttons may be used to select the desired array. The enter key will accept the selected array. To measure the actual angle of downtilt controller 80 drives a motor 41 of an array to drive member 34 to the right. Motor 41 is driven until threaded member 34 abuts switch 46. The controller 80 counts the number of pulses from reed switch 43 to determine how far threaded portion 34 has traveled. At the extreme right position the controller 80 determines and displays the angle of downtilt, calculated in accordance with the number of pulses connected from reed switch 43. The controller 80 then drives threaded member 34 back in the opposite direction for the same number of pulses from reed switch 43 so that it returns to the same position. The angle of downtilt for each antenna may be stored in memory of controller 80. This value will be updated whenever the actual angle of downtilt is measured in this way. The "measure tilt" function may not be used if the controller is locked.

Controller 80 may include tables in memory containing the number of pulses from reed switch 43 that must be counted for threaded member 34 to achieve each desired degree of downtilt. This may be stored as a table containing the number of pulses for each required degree of downtilt, which may be in 0.1° steps. This approach ensures that any non-linearities of the antenna may be compensated for as the tables will give the actual amount of movement required to achieve a desired downtilt for a given antenna.

The "enable array" function may be used to enable each array when installed. The controller 80 will be prevented from moving any array that has not been enabled. Controller 80 will record in memory which arrays have been enabled. The "disable array" function may be used to disable arrays in a similar manner.

The "lock controls" function may be used to lock the controller once adjustment has been made. A "rack error" signal may be displayed if the array has not operated correctly. This will indicate that an operator should inspect the array.

Adjustment of the array may also be performed remotely. Controller 80 may be connected to modem 86 via serial line 87 which may connect via telephone line 88 to a central controller 89. Alternatively, the controller 80 may be connected to a central controller 89 via a radio link etc. The functions previously discussed may be effected remotely at central controller 89. In a computer controlled system adjustments may be made by a computer without operator intervention. In this way, the system can be integrated as part of a control strategy for a cellular base station. For example, a remote control centre 89 may adjust the downtilt of antennas at a cellular base station remotely to adjust the size of the cell in response to traffic demand. It will be appreciated that the capability to continuously and remotely control the electrical downtilt of a number of antenna of a cellular base station may be utilised in a number of control strategies.

Central controller 89 may be a computer, such as an IBM compatible PC running a windows based software program. A main screen of the program may show information regarding the antenna under control as follows:

	NAME	TYPE ANGLE	CURRENT VALUE	NEW	STATUS
GROUP 1					
antenna 1	1 south	VT01	12°	12.5°	setting
antenna 2	1 north	VT01	12°	12.5°	queued
antenna 3	1 west	VTO1	12°	12.5°	queued
GROUP 2					
antenna 4	2 south	VT01	6°		pending
antenna 5	2 north	VT01	6°	.5°	nudging
antenna 6	2 west	VTO1	6°		faulty

The antennas may be arranged in groups at each site. Group 1 for example contains antennas 1, 2 and 3. The following information about each antenna is given:

Name: this is the user assigned name such as 1 south, 1 north, 1 west etc.

Type: this is the antenna type which the controller communicates to the PC at start-up.

Current Angle: this is the actual degree of beam tilt of an antenna which is communicated from the controller to the PC at start-up. The controller also supplies to the PC each antennas minimum and maximum angles of tilt.

New Value: by moving a pointer to the row of an antenna and clicking a button of a mouse the settings of an antenna may be varied. When a user clicks on the mouse the following options may be selected:

- Name—the user may change the group or antenna name.
- Adjust—a user may enter a new angle in the "new value" column to set the antenna to a new value.
- Nudge—the user may enter a relative value (i.e.: increase or decrease the tilt of an antenna by a predetermined amount).
- Measure—the controller may be instructed to measure the actual angle of tilt of an antenna or group of antennas.

If an antenna is in a "fault" condition then it may not be adjusted and if a user clicks on a mouse when that antenna is highlighted a dialogue box will appear instructing the user to clear the fault before adjusting the antenna.

Each antenna also includes a field indicating the status of the antenna as follows:

- O.K.—the antenna is functioning normally.
- Queued—an instruction to read, measure, set or nudge the antenna has been queued until the controller is ready.
- Reading—when information about an antenna is being read from the controller.
- Measuring—when the actual degree of tilt of the antenna is being measured.
- Setting—when a new tilt angle is being set.
- Nudging—when the tilt angle of the antenna is being nudged.
- Faulty—where an antenna is faulty.

When adjusting, measuring or nudging an antenna a further dialogue box may appear describing the action that has been instructed and asking a user to confirm that the action should be taken. This safeguards against undesired commands being carried out.

Information for a site may be stored in a file which can be recalled when the antenna is to be monitored or adjusted again. It will be appreciated that the software may be modified for any required control application.

Controller **80** may be a fixed controller installed in the base of an antenna site or could be a portable control unit which is plugged into connectors from control lines **78**.

Where in the foregoing description reference has been made to integers or components having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope or spirit of the present invention.

INDUSTRIAL APPLICABILITY

The present invention may find particular application in antenna systems, such as those used in cellular communication systems.

What is claimed is:

1. A method of adjusting a fixed beam elevation in a cellular base station telecommunication system, the system having a panel antenna adapted to mount a plurality of vertically spaced radiating elements, the method comprising:

   providing a differential electromechanical phase shifter having a transmission line section coupled to said radiating elements, and a transmission line input which is moveable relative to said transmission line section to differentially adjust physical path lengths of transmission line outputs to said coupled radiating elements;

   operatively linking a first controller to said electromechanical phase shifter;

   operatively coupling a second controller to said first controller from a location remote from said first controller; and

   employing said first and second controllers and from the location of said second controller effecting controlled movement of said transmission line input relative to said transmission line section to adjust the beam from a first fixed elevation to a second fixed elevation.

2. The method defined by claim 1 wherein said controlled movement is produced by an electric motor located at the antenna which is mechanically coupled to said phase shifter and electrically coupled directly to said first controller.

3. The method of claim 2 wherein said controlled movement is effected by motor-driven drive devices selected from the group consisting of a screw drive, rack-and-pinion drive, and gear drive.

4. The method of claim 2 wherein said motor is a pulse driven motor, and wherein said method includes:

   causing the motor to displace said transmission line input to a displacement limit position corresponding to a predetermined signal phasing; and

   providing a predetermined number of pulses to the motor to cause the motor to displace said transmission line input away from said displacement limit position by a predetermined amount so as to achieve a predetermined beam elevation.

5. The method of claim 1 wherein the phase shifter has plastic components to reduce intermodulation distortion.

6. The method of claim 1 wherein said phase shifter is adapted to adjust beam elevation selected in response to traffic demands.

7. The method of claim 1 wherein at least one of said operatively linking and operatively coupling steps uses a wireless link.

8. The method of claim 7 further including the step of configuring said wireless link as a radio link.

9. The method of claim 1 further including the step of locking said phase shifter after it has been adjusted.

10. The method of claim 1 wherein said first and second controllers control said phase shifter through a telephone link.

11. The method of claim 1 wherein at least one of said controllers is personal computer.

12. The method of claim 1 further including the step of locating said first controller at an antenna support structure, and remotely locating said second controller from said first controller.

13. The method of claim 1 further including the step of locating said first and second controllers remotely from said antenna.

14. The method of claim 1 further including the step of adjusting said phase shifter to produce an increase in an elevation angle of the beam or a decrease in an elevation angle of the beam, said adjusting performed by at least one of said first and second controllers.

15. The method of claim 1 including the step of adjusting said phase shifter to produce selected different phasing of signals supplied to at least selected radiating elements, said adjusting performed by at least one of said first and second controllers.

16. The method of claim 1 including the step of adjusting a phasing of signals supplied to at least selected radiating elements by predetermined amounts, said adjusting performed by at least one of said first and second controllers.

17. The method of claim 1 including the step of measuring a phase value of signals supplied to at least selected radiating elements, said measuring performed by at least one of said first and second controllers.

18. A cellular base station telecommunication system, comprising:

- a panel antenna adapted to mount a plurality of spaced radiating elements producing a beam having a fixed elevation;
- a differential electromechanical phase shifter having a transmission line section coupled to said radiating elements and a transmission line input which is moveable relative to said transmission line section to differentially adjust physical path lengths of transmission line outputs to the coupled radiating elements;
- an electric motor mechanically coupled to said phase shifter;
- a first controller operatively linked to said electromechanical phase shifter; and
- a second controller operatively linked to said first controller, said first and second controllers being configured to effect displacement of said transmission line input relative to said transmission line section to adjust the beam from a first fixed elevation to a second fixed elevation.

19. The system of claim 18 configured to adjust selected beam elevation in response to traffic demands.

20. The system of claim 18 wherein said controlled movement is effected by drive devices selected from the group consisting of a screw drive, rack-and-pinion drive, and gear drive.

21. The system of claim 18 wherein at least one of said links is a telephone link.

22. The system of claim 18 wherein at least one of said links is a wireless link.

23. The system of claim 22 wherein said wireless link is a radio link.

24. The system of claim 18 further including a phase shifter lock.

25. The system of claim 18 wherein at least one of said controllers is a personal computer.

26. The system of claim 18 further including an antenna support structure wherein said first controller is located at said antenna support structure.

27. The system of claim 18 further including an antenna support structure wherein at least one of said first and second controllers is located remotely from said antenna support structure.

28. The system of claim 18 adapted to adjust a phasing of signals supplied to the radiating elements so as to cause an increase in an elevation angle of the beam or a decrease in an elevation angle of the beam.

29. The system of claim 18 adapted to select a predetermined phasing of signals supplied to at least selected radiating elements.

30. The system of claim 18 adapted to change a phase of the signals supplied to at least selected radiating elements by predetermined amounts.

31. The system of claim 18 adapted to measure a phase value of signals supplied to at least selected radiating elements.

32. The system of claim 18 adapted to identify a status of said antenna.

33. The system of claim 18 wherein at least one of said controllers is a portable or handheld device.

34. The system of claim 18 further including an antenna support structure, and wherein said first controller is located at said support structure and said second controller is remotely located from said support structure.

35. The system of claim 34 wherein said first and second controllers are coupled by a wireless link.

36. The system of claim 34 wherein said first controller is coupled to said phase shifter by a wire.

37. An antenna control arrangement for use in or with a cellular base station telecommunication system, the system having an electromechanical phase shifter and an antenna with a plurality of radiating elements coupled to a feed network, the control arrangement comprising a hierarchical organization of controllers coupled to and operatively controlling said electromechanical phase shifter.

38. The control arrangement defined by claim 37 further including a first controller operatively coupled to and controlling said phase shifter, and a second controller operatively coupled to and controlling said first controller.

39. The control arrangement defined by claim 38 wherein said first controller is located near said antenna, and wherein said second controller is located remotely from said first controller.

40. The control arrangement defined by claim 38 wherein said first and second controllers are coupled by a wireless link.

41. The control arrangement of claim 37 wherein at least said second controller is a personal computer.

42. The control arrangement of claim 37 wherein at least said first controller is a portable or handheld device.

43. An antenna control arrangement for use in or with a cellular base station telecommunication system, the antenna control arrangement comprising:

- an antenna with a plurality of radiating elements;
- the antenna coupled to a feed network having a power-dividing differential electromechanical phase shifter; and
- first and second controllers for communicating control signals to said electromechanical phase shifter.

44. The control arrangement of claim 43 wherein at least one of said first and second controllers is remotely located remotely from said antenna control arrangement.

45. The control arrangement of claim 43 wherein at least said second controller is a personal computer.

46. The control arrangement of claim 43 wherein at least said first controller is a portable or handheld device.

47. A cellular base station telecommunication system having an antenna with a plurality of radiating elements coupled to a feed network, the system comprising:

an electromechanical phase shifter having at least one movable component such that a relative displacement of the at least one moveable component varies a physical path length of signals supplied to at least selected radiating elements;

a motor coupled to at least one of said moveable components, and

a first controller configured to provide drive signals to said motor.

48. The system of claim 47 wherein said motor is a stepper motor.

49. The system of claim 48 wherein said first controller is configured to supply a predetermined number of drive pulses to said stepper motor.

50. The system of claim 47 wherein said motor is located on said antenna.

51. The system of claim 47 wherein said motor is mechanically coupled to said phase shifter and drives said phase shifter.

52. The system of claim 47 wherein said first controller is remotely located from said antenna.

53. The system of claim 47 further including a second controller operatively coupled to and controlling said first controller.

54. The system of claim 53 wherein the second controller is a portable or handheld device.

55. A cellular base station telecommunication system, the system developing a beam, the system comprising:

an antenna having a plurality of radiating elements;

a signal feed network operatively coupled to said radiating elements;

an electromechanical phase shifter formed as part of said signal feed network; and

a portable or handheld controller configured to control said phase shifter.

56. A method for adjusting a beam of a cellular base station telecommunication system, the system having an antenna with a plurality of radiating elements driven through a signal feed network to develop the beam, a method comprising the steps of:

providing an electromechanical phase shifter that forms a part of the signal feed network; and

controlling said phase shifter with a portable or handheld controller.

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(54) ANTENNA SYSTEM

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(57) **ABSTRACT**

An antenna assembly for emitting a signal. The antenna assembly includes at least two antennas which are separated into a first group and a second group. Both groups of antennas are mounted on a panel. A first phase adjuster is coupled to the first antenna group. The first phase adjuster is also coupled to a second phase adjuster, which is also coupled to said second antenna group. The first phase adjuster is coupled to the second phase adjuster, such that an adjustment of the first phase adjuster causes an adjustment of the second phase adjuster. The first phase adjuster is adapted to adjust a phase angle of the signal of the first antenna group, while the second phase adjuster is adapted to adjust a phase angle of the signal of said second antenna group.

55 Claims, 8 Drawing Sheets

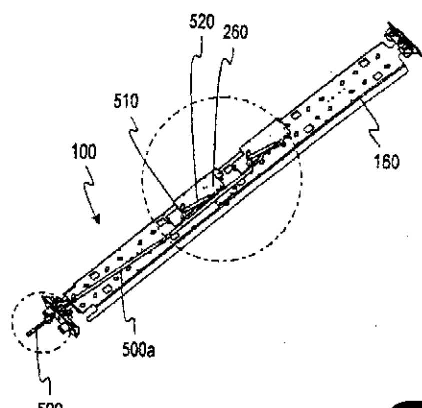

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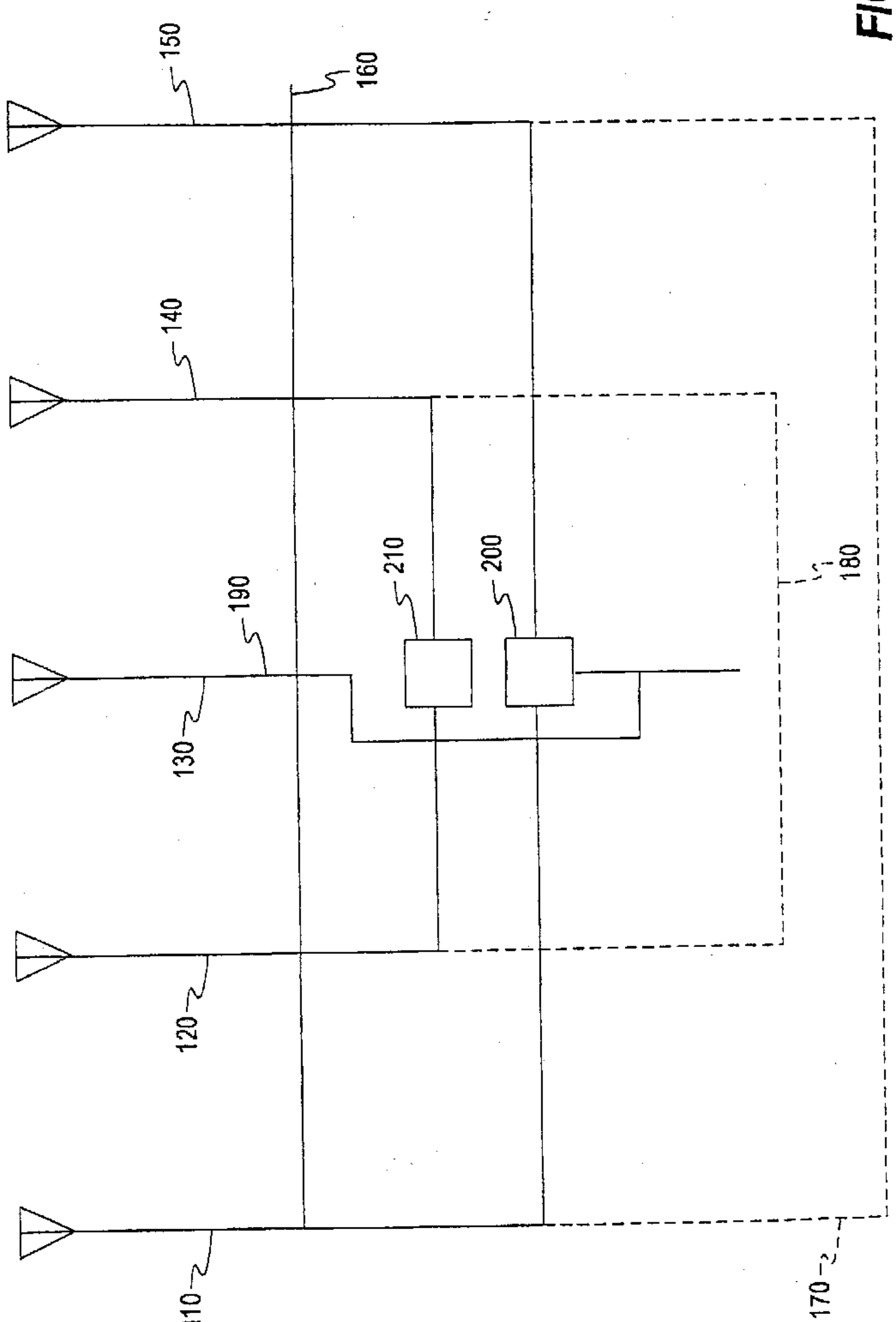
FIG. 1



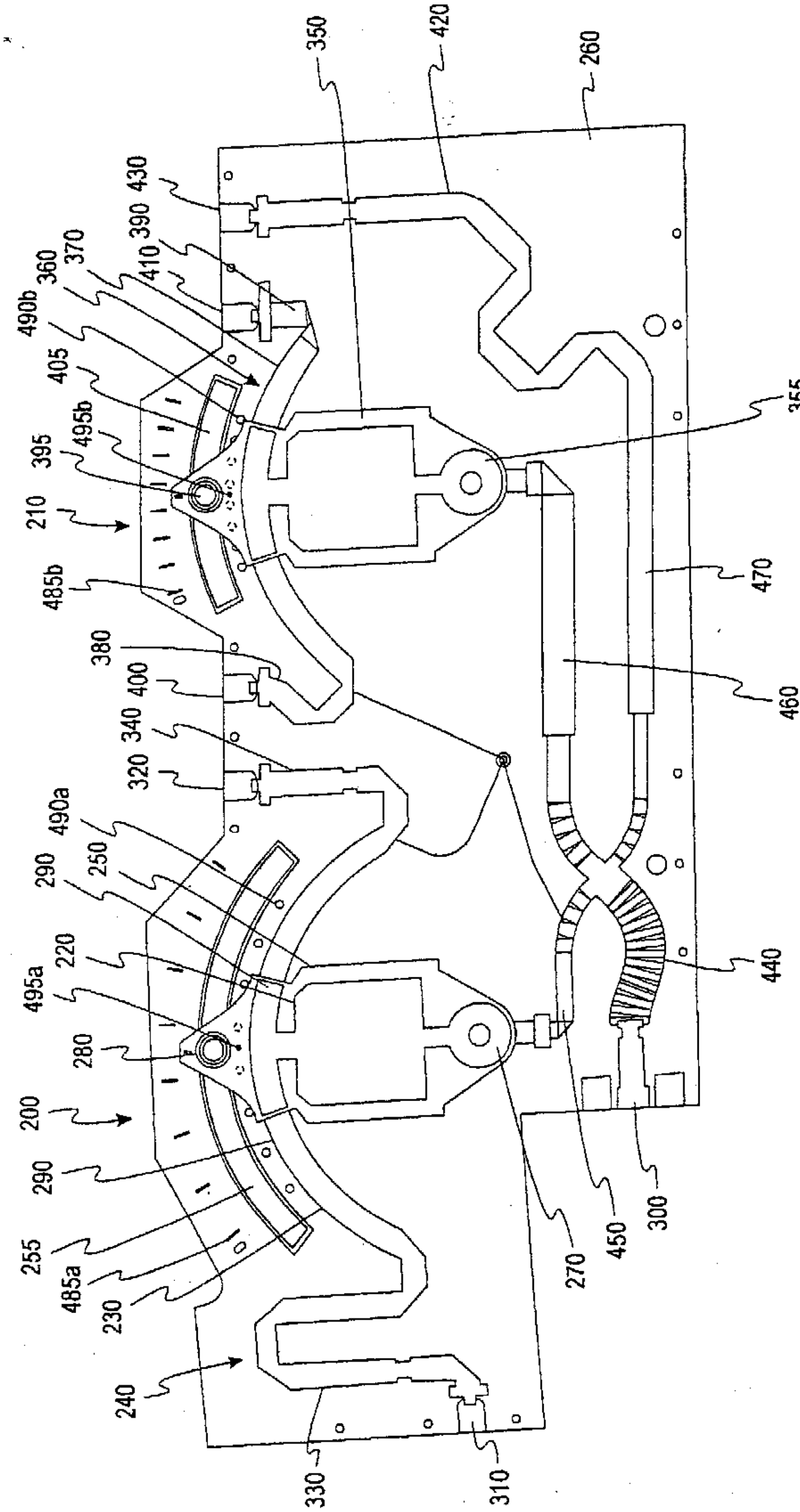

350
420
260
430
390
410
370
360
490b
405
495b
395
210
485b
380
400
340
320
490a
250
290
220
495a
280
200
290
255
485a
230
240
330
310
270
450
300
440
460
470
355

FIG. 2

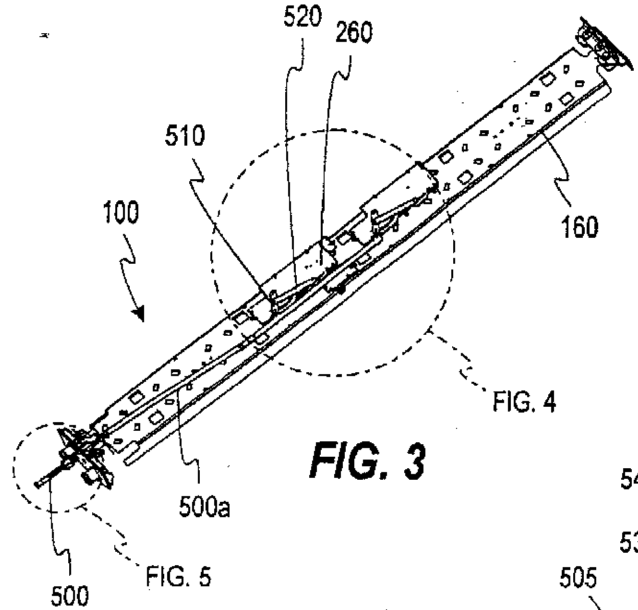


FIG. 3

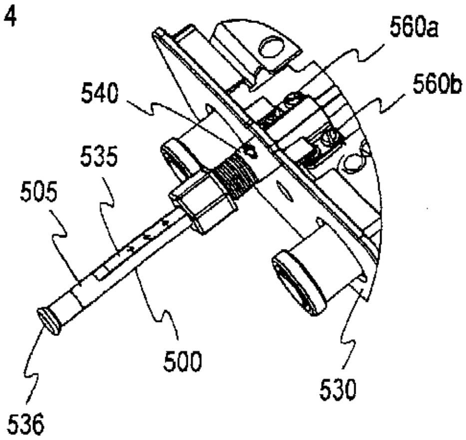


FIG. 5

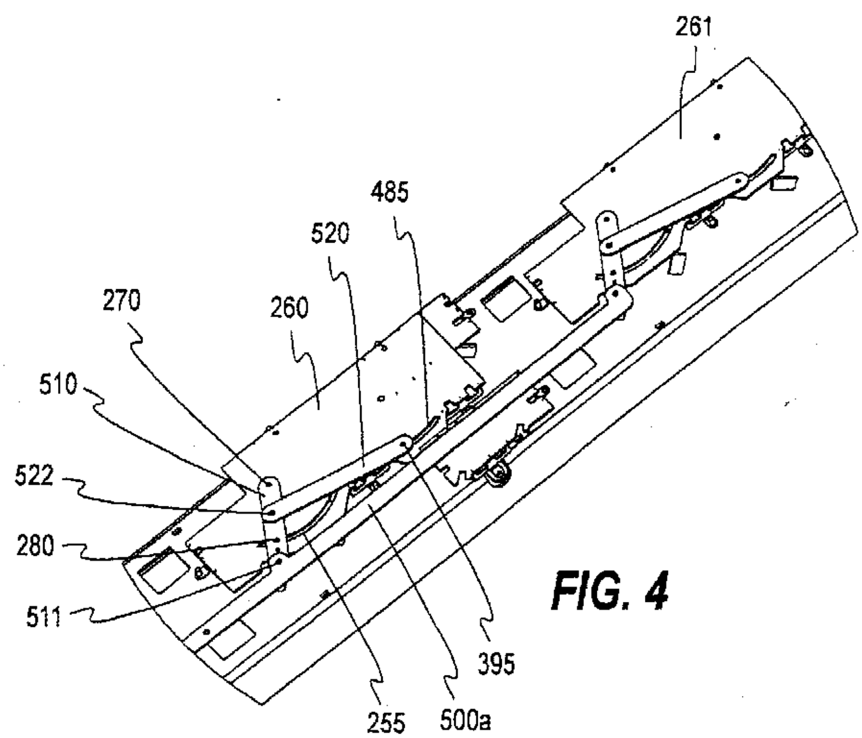


FIG. 4

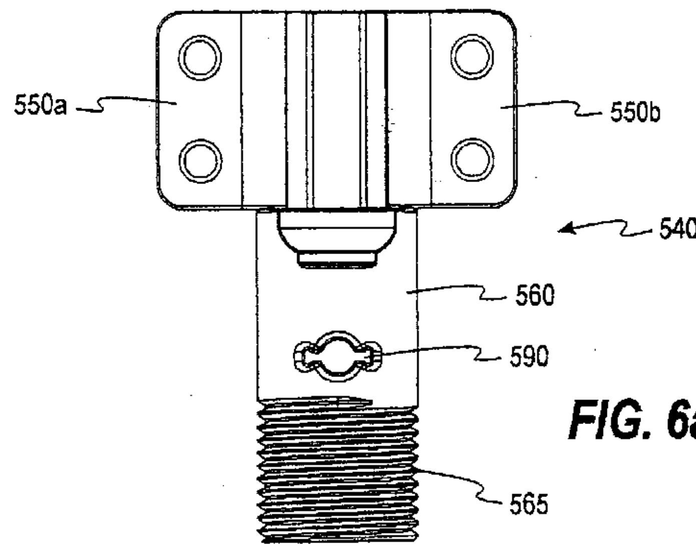


FIG. 6a

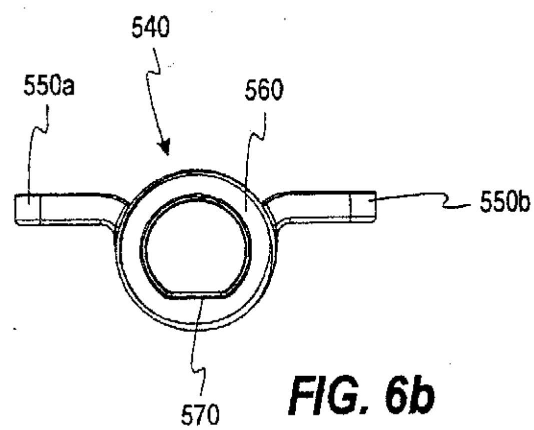


FIG. 6b

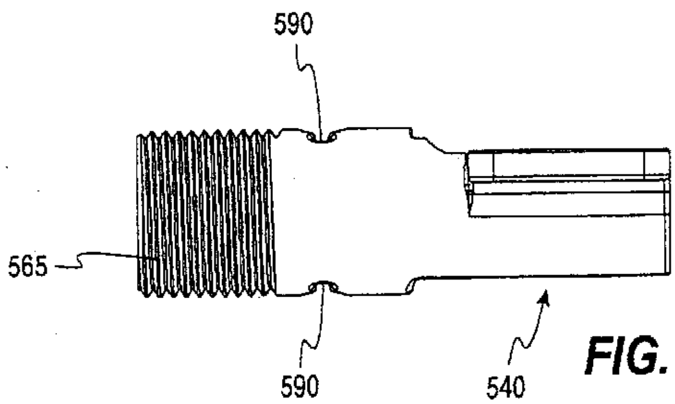


FIG. 6c

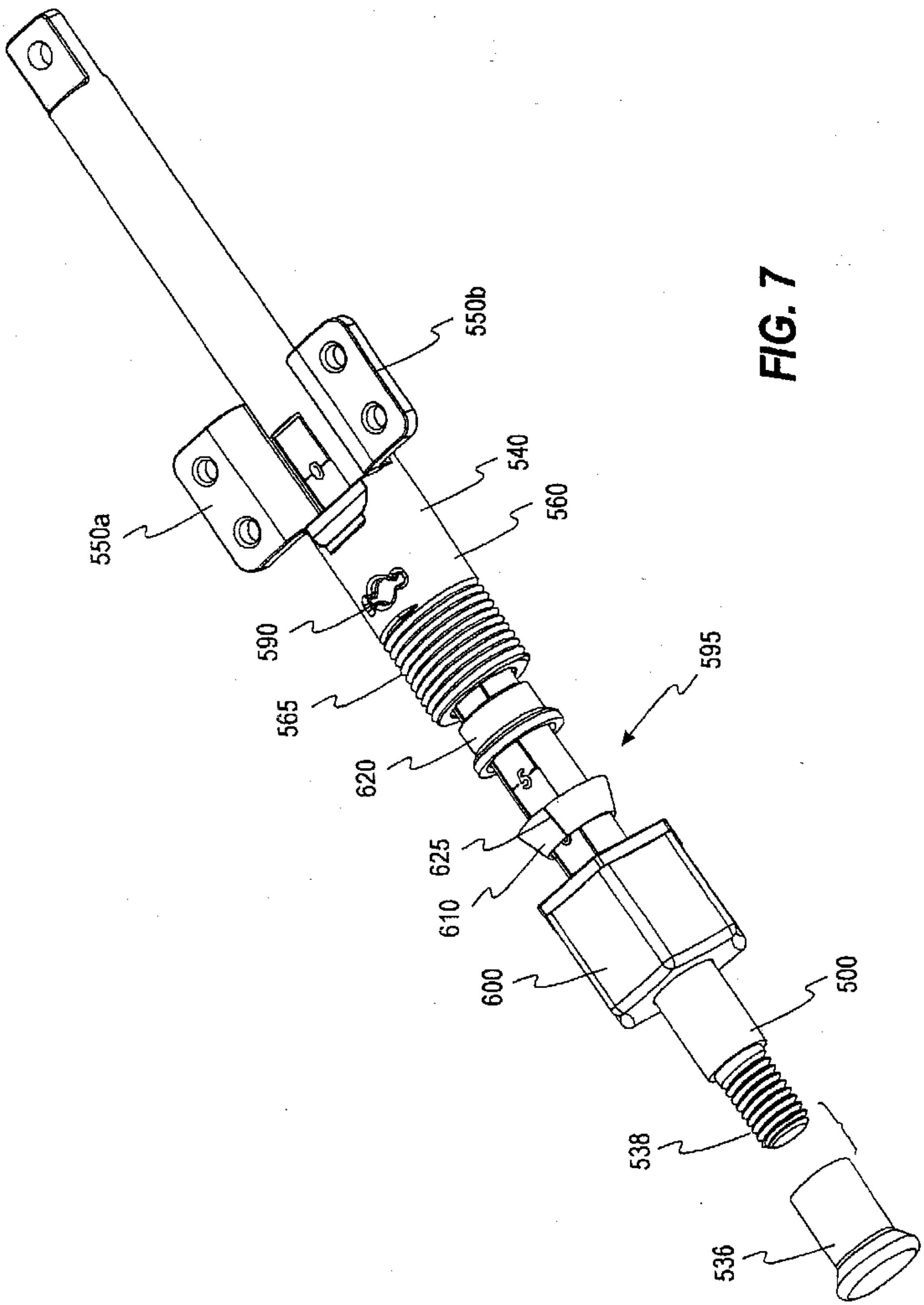


FIG. 7

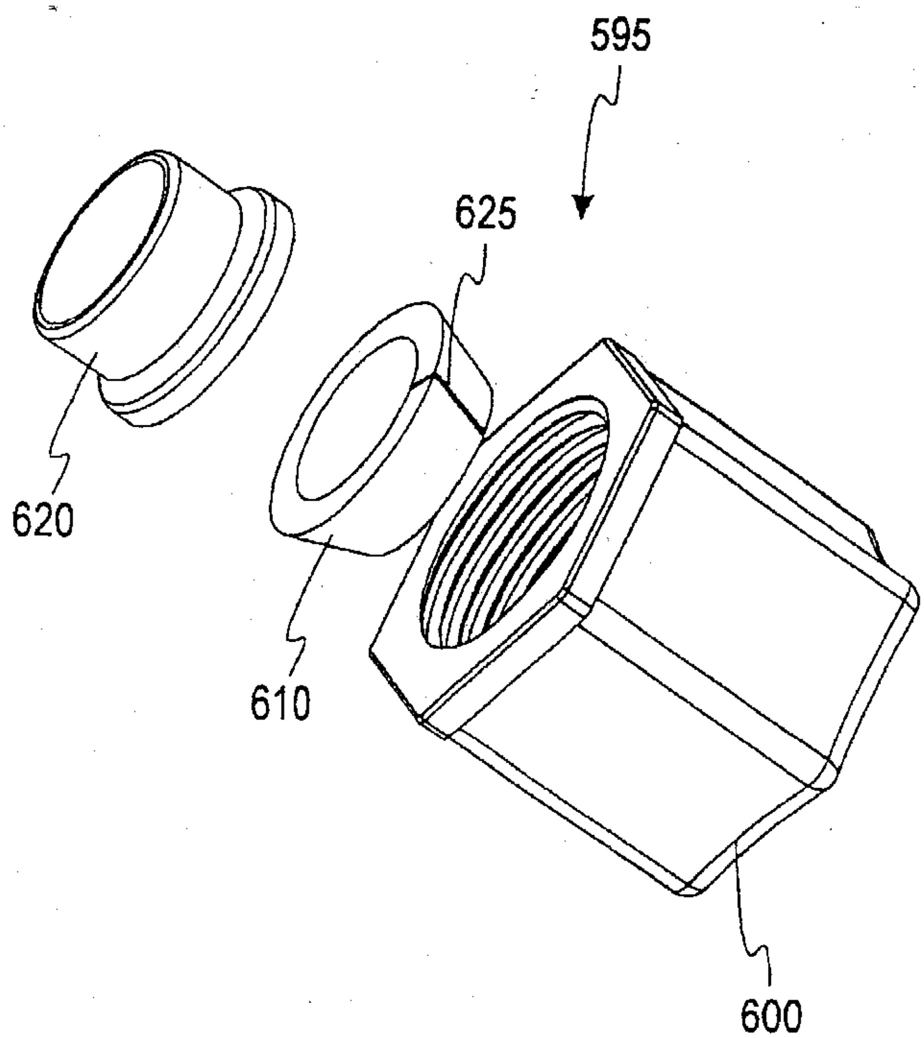


FIG. 8

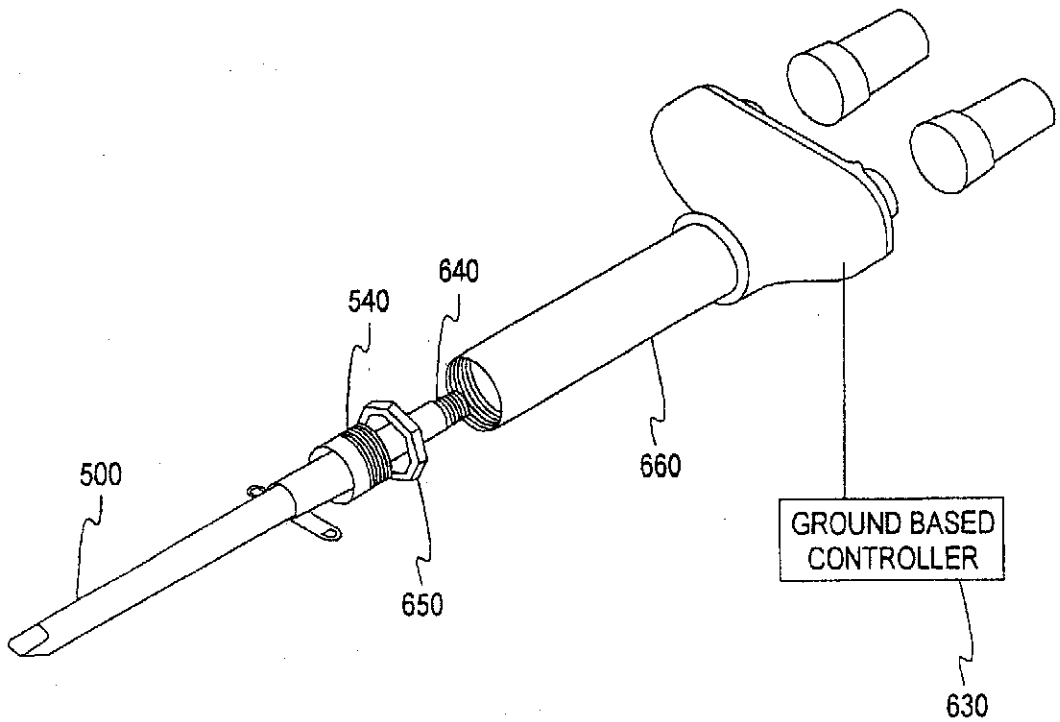


FIG. 8A

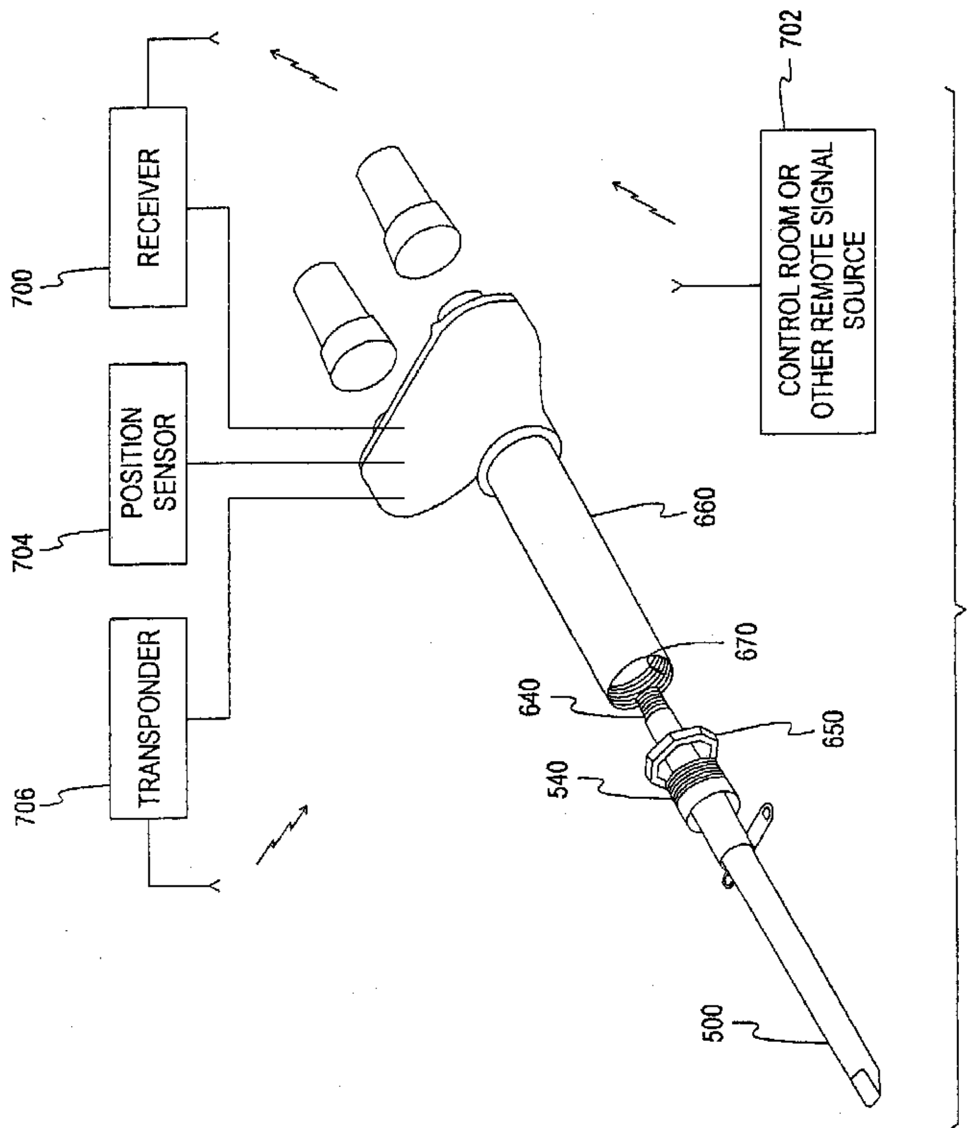

RECEIVER
POSITION SENSOR
TRANSPONDER
CONTROL ROOM OR OTHER REMOTE SIGNAL SOURCE
700
702
704
706
660
670
640
650
540
500

FIG. 9

ANTENNA SYSTEM

BACKGROUND OF THE INVENTION

In many passive antenna assemblies, it is often desired to be able to adjust a radiation pattern of the antenna assembly after the antenna assembly has been installed on a tower. The need may arise due to a number of factors, including new construction, which may create obstacles, vegetation growth, or other changes in the surrounding environment. It may also be desired to alter the radiation pattern due to performance studies or to alter the shape of the area the antenna covers.

There are various ways that the radiation pattern may be altered. One method is to physically change the location of the antenna assembly. Once the assembly has been installed on a tower, however, this becomes difficult. It is also possible to change the azimuth and elevation of the individual antennas, but such a method is expensive when applied to several antennas. Also, the mechanical device required to adjust the azimuth and elevation may interfere with the mechanical antenna mount.

Another method that has been utilized to adjust the radiation pattern of a number of antennas grouped onto one antenna assembly is to alter the phase angle of the individual antennas. By altering the phase angle of the individual antennas, a main beam (which causes the radiation pattern) is tilted relative to the surface of the earth. The antennas are grouped into a first group, a second group, and a third group. All three groups are disposed along a panel of the antenna assembly. A phase adjuster is disposed between two of the antenna groups, such that an adjustment of the phase adjuster changes the radiation pattern. The phase adjuster comprises a conductor coupled with a transmission line to create a capacitor. The conductor is rotatable and moves along the transmission line, changing the location of the capacitor on the transmission line. The transmission line is coupled to an antenna which has a phase angle. The phase angle is dependant partially on the location of the capacitor. Thus, by changing the location of the capacitor, the phase angle is changed. The phase adjuster may be coupled to a plurality of antennas and acts to adjust the phase angle of all of them.

The phase adjusters currently in use, however, have numerous drawbacks. First, the conductor is often made of brass which is expensive to etch and cut. Therefore, the conductor is usually cut in a rectangular shape. The path of the transmission line, however, is arcuate. The conductor does not cover the entire width at the capacitor, which decreases the effectiveness of the capacitance.

Another problem with current phase adjusters is the coupling of a power divider to the phase adjuster. The antenna assembly receives power from one source. Each of the three groups of antennas, however, has different power requirements. Thus, power dividers must be connected to the assembly. Currently, a power divider may be a series of cables having different impedances. Using a variety of cables makes manufacturing difficult since the cables have to be soldered together. Also, since manual work is required, the chances of an error occurring is increased. Another method of dividing the power is to create a power divider on a PC board and then cable the power divider to the phase adjuster. Although this decreases some costs, it still requires the extensive use of cabling, which is a disadvantage.

A third problem is caused by the use of cable lines having different lengths to connect an antenna to the appropriate output from the phase adjuster. Each antenna has a different default phase angle when the phase adjuster is set to zero. The default phase angle is a function of the cable length coupled with the length of the transmission line. To achieve the differing default phase angles, cables of varying lengths are attached to different antennas. Although this only creates a slight increase in manufacturing costs since cables of varying lengths must be purchased, it greatly increases the likelihood of error during installation. In numerous antenna assemblies, the cable lengths only differ by an inch or less. During assembly, if a cable is not properly marked, it may be difficult for the person doing the assembly to tell the difference between the different sizes of cable.

To move the phase adjuster, an actuator is located on a side of the panel and may include a small knob or rotatable disc for manually changing the phase adjuster. Thus, whenever the radiation pattern needs to be adjusted, a person must climb the tower and up the side of the panel to the phase adjuster. This is a difficult and time consuming process. Also, it is only possible to move the actuator manually, requiring the exertion of physical labor. In addition, it is a dangerous activity since the antennas are located on a tower and it is possible for a person to fall or otherwise become injured in the climbing process.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings.

FIG. 1 is a schematic of an antenna assembly of the present invention.

FIG. 2 is a schematic view of a phase adjuster assembly according to one embodiment of the present invention.

FIG. 3 is perspective side view of a panel and the phase adjuster assembly according to one embodiment of the present invention.

FIG. 4 is an enlarged view of section B shown in FIG. 3.

FIG. 5 is an enlarged view of section A shown in FIG. 3.

FIG. 6*a* is a front view of a bushing mount according to one embodiment of the present invention.

FIG. 6*b* is an end view of a bushing mount according to one embodiment of the present invention.

FIG. 6*c* is a side view of a bushing mount according to one embodiment of the present invention.

FIG. 7 is an exploded perspective view of an actuator rod according to one embodiment of the present invention.

FIG. 8 is a perspective view of a compression nut according to one embodiment of the present invention.

FIG. 8A is a perspective view of an actuator rod and an electrical actuator having a ground-based controller according to one embodiment of the present invention.

FIG. 9 is a perspective view of an actuator rod and an electrical actuator according to one embodiment of the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

FIG. 1 is a side view of an antenna assembly **100** of the present invention. The antenna assembly **100** is comprised of a plurality of antennas **110**, **120**, **130**, **140**, **150** disposed along a panel **160**. The antennas **110**, **120**, **130**, **140**, **150** are grouped into a first group **170**, a second group **180**, and a third group **190**. The first antenna **110** and the fifth antenna **150** are in the first group **170**. The second antenna **120** and the fourth antenna **140** are in the second group **180** and the third antenna **130** is in the third group **190**.

To adjust the radiation pattern, the vertical electromagnetic beam of the antenna assembly **100** must be adjusted. This is accomplished by adjusting the phase angle of the first group **170** relative to the second group **180**. The first group **170**, however, must be adjusted by an amount different than the amount of the second group **180**. To accomplish this, a first phase adjuster **200** is attached to the first group **170**, and a second phase adjuster **210** is attached to the second group **180**. The adjustment amount of the second group **180** is often a function of the amount of adjustment of the first group **170**. To ensure that the first and second groups **170**, **180** are adjusted in the correct ratio, the second adjuster **210** may be connected to the first adjuster **200**, such that an adjustment of the first adjuster causes an adjustment of the second adjuster. More particularly, the second phase adjuster **210** may be connected to the first phase adjuster **200**, such that an adjustment of the first phase adjuster **200** for a predetermined distance causes the second phase adjuster **210** to move proportional to the distance.

FIG. 2 depicts a schematic view of a first and second phase adjusters **200**, **210** respectively, adapted to adjust the vertical beam or vertical beam downtilt angle. The first phase adjuster **200** is coupled to the first antenna group **170**, and the second phase adjuster **210** is coupled to the second antenna group **180**. Each of the plurality of antennas **110**, **120**, **130**, **140**, **150** has a different phase angle. By adjusting the phase angles of the plurality of antennas **110**, **120**, **130**, **140**, **150**, or at least of the first and second groups **170**, **180** of antennas, the vertical beam of the antenna assembly **100** is adjusted.

The first and second phase adjusters **200**, **210** operate in the same fashion. For simplicity, the description will be described in more detail regarding the first phase adjuster **200**. To adjust the phase angle, a conductive wiper **220** slides over a first arcuate portion **230** of a first transmission line **240**. One end of the first transmission line **240** is coupled to the first antenna **110**, while the other end of the first transmission line **240** is coupled to the fifth antenna **150**. The conductive wiper **220** in connection with the first arcuate portion **230** acts as a capacitor. To the antennas **110**, **150**, the capacitor is seen as a short circuit at high frequencies. The length of the first transmission line **240** up to the point of the short circuit affects the phase angle of the antenna. As the conductive wiper **220** slides over the first arcuate portion **230**, the location of the short circuit changes, changing the length of the first transmission line **240** and, thus, the phase angle of the two antennas **110**, **150**. Since the antennas **110**, **150** are located at opposite ends of the first transmission line **240**, the movement of the short circuit lengthens one transmission line as seen by one antenna while shortening the transmission line as seen by the other antenna. In other words, the transmission line has a finite length. The finite length of the transmission line is divided into a first effective length and a second effective length. The first effective length is from the first antenna **110** to the location of the wiper **220** on the transmission line **240**. The second effective length is measured from the fifth antenna **150** to the location of the wiper **220** on the transmission line **240**. As the wiper **220** is adjusted towards the fifth antenna **150**, the first effective length is lengthened while the second effective length is shortened. As the wiper **220** is adjusted towards the first antenna **110**, the first effective length is shortened while the second effective length is lengthened.

In this particular embodiment, the conductive wiper **220** is a first rotatable PC board **250** with a metallic side. The first transmission line **240** is mounted on a separate fixed PC board **260**. The fixed PC board **260** and first rotatable PC board **250** act as a dielectric between the capacitor. In prior art systems, an air dielectric was sometimes used. If the conductive wiper changes its spacing relative to the first arcuate portion **230**, however, the capacitor's capacitance is altered, thus, changing the impedance match of the phase shifter. If the two sections touch, the capacitance is destroyed, which adversely affects the performance of the antenna even more. Other systems use a sheet dielectric to separate the conductive wiper from the transmission line which have to be mounted using standoffs and point fasteners. The sheet, however, tends to attenuate the capacitive effect. By using the PC boards as the dielectric, the conductive wiper cannot touch the transmission line nor are the capacitive effects attenuated. Also, the manufacturing costs for making the PC board are much lower than having to mount the sheet dielectric.

The first rotatable PC board **250** is pivotally connected to the fixed PC board **260** at a joint **270**, which acts as the pivot point for the first rotatable PC board **250**. At another end, a joint **280**, the first rotatable PC board **250** is slidably mounted in a first slot **255**. A mechanical actuator (to be described) including an actuator rod **500** and a main arm **500*a*** moves the first rotatable PC board **250** in an arcuate path over the first arcuate portion **230**, thus changing the phase angle of the antennas **110**, **150** as discussed above.

To increase the capacitive effects, an end **290** of the first rotatable PC board **250** that glides over the first arcuate portion **230** may be curved. The radius of curvature of the end **290** of the first rotatable PC board **250** is the same as the radius of curvature of the first arcuate portion **230**. Also, both the first rotatable PC board **250** and the first arcuate portion **230** have the same center point located at the joint **270**. By completely aligning with the arcuate portion **230**, the capacitance is increased, increasing the effectiveness of the first phase adjuster **200**.

The first transmission line **240** is electrically connected to an input **300** for receiving power. The first rotatable PC board **250** is also electrically connected to the input **300**. The first transmission line **240** is coupled to the first antenna **110** (shown in FIG. 1) at a first output **310**, and also to the fifth antenna **150** (shown in FIG. 1) at a fifth output **320**. Each of the antennas **110**, **150** has a default phase angle when the capacitor is set to zero, which is marked on FIG. 2. The default phase angle of antenna **110** is a function of the length of the first transmission line **240** and a cable line (not shown) connecting the first transmission line **240** to the antenna **110**. The first transmission line **240** includes a first path **330** leading from the first arcuate portion **230** to the first output **310**. The length of the first path **330** is determined by the default phase angle of the first antenna **110**. The first transmission line **240** also has a second path **340** connecting the first arcuate portion **230** to the fifth output **320**. The length of the second path **340** is determined by the default angle of the fifth antenna **150**. By varying the length of the first path **330** and the fifth path **340**, the same length cables can be used during installation to connect the antennas to the output, which makes installation easier.

The second phase adjuster **210** acts in the same way as the first phase adjuster **200**. A second rotatable PC board **350** is mounted on the fixed PC board **260** and is electrically coupled to the input **300**. The second rotatable PC board **350** is rotatable around a joint **355**, which is also where the second rotatable PC board **350** is connected to the fixed PC board **260**. A second transmission line **360** having a second arcuate portion **370**, a first path **380**, and a second path **390** is also electrically connected to the input **300**. The second rotatable PC board **350** glides over the second arcuate portion **370** to create the capacitor. The second rotatable PC board **350** is moved by mechanical actuator comprising actuator rod **500** and main arm **500a**. Main arm **500a** is connected through a linkage to be described to the board **350** at a joint **395** located in a second slot **405** in the fixed PC board **260**. The first path **380** of the second transmission line **360** is connected to a second output **400**, which is coupled to the second antenna **120** (FIG. **1**), while the second path **390** of the second transmission line **360** is connected to a fourth output **410**, which is coupled to the fourth antenna **140**. As with the first phase adjuster **200**, the lengths of the first and second paths **380**, **390** are adjusted to create the proper default phase angle.

Also connected to the input **300** is a third transmission line **420**, which is coupled to a third output **430**, which is connected to the third antenna **130**. The third transmission line **420** is of a length to create the proper default phase angle. Since all of the individual paths **330**, **340**, **380**, **390**, **420** of the various transmission lines **240**, **360**, **420** are adjusted to create the proper default phase angle, the same length cable can be used to connect the antennas **110**, **120**, **130**, **140**, **150** to their respective outputs **310**, **400**, **430**, **410**, **320**. This not only makes manufacturing easier, it also eliminates the possibility of error during installation of connecting the wrong length cable to the output.

The input **300** is connected to a conductive strip **440** which acts as a power divider and bleeds off power to the first and second phase adjusters **200**, **210** and the third transmission line **420**. The conductive strip **440** has an established impedance. The impedance of the strip **440** is a function of the width of the strip **440**. By changing the width of the conductive strip **440**, the impedance and, thus, the power is changed. In the present invention, the conductive strip **440** branches into a first strip **450**, a second strip **460**, and a third strip **470**. The first strip **450** transfers power from the conductive strip **440** to the first phase adjuster **200**. The second strip **460** transfers power from the conductive strip **440** to the second phase adjuster **210**, and the third strip **470** transfers power from the conductive strip **440** to the third transmission line **420**. The width of each of the first, second, and third strips **450**, **460**, **470** is manufactured to draw the correct amount of power from the conductive strip (or power divider) **440**. By using a power divider on the fixed PC board **260**, excess cables are eliminated, which decreases cost and also increases the reliability of the antenna assembly **100**. In another embodiment of the present invention, a conductive strip can be included to divide power on the first and second transmission lines **240**, **360** along the arcuate portions **230**, **370**.

It is sometimes desirable to lock the first and second phase adjusters in a permanent position. In current systems, a phase adjuster was locked into position at the time of manufacture since the phase adjuster does not include markings or the like. In one embodiment of the present invention, however, the fixed PC board **260** includes a first set of markers **480a** over the first slot **255** and a second set of markers **480b** over the second slot **405**. The sets of markers **485a**, **485b** provide a user with a method for viewing the phase angle settings of the first and second phase adjusters **200**, **210**. A locking mechanism **485** is included to lock the first and second phase adjusters **250**, **350** in a set position. In one embodiment, a series of through holes **490a**, **490b** may also be included on the fixed PC board **260** and align with through holes **495a**, **495b** on the first and second rotatable PC boards **250**, **350**. A screw (not shown) may be used to lock the first or second first rotatable PC board **250**, **350** to the fixed PC board **260**. The use of markings and a lock system is a great improvement because the fixed PC board **260** can be assembled to the first and second phase adjusters **200**, **210** without knowing if the phase angles need to be locked. Thus, this device may be manufactured prior to a purchase order being received. Once a purchase order is made, the markings and lock system can be used to lock the first and second phase adjusters **200**, **210** in place, if so desired.

Turning now to FIGS. 2–4, FIG. 2 depicts a front side of the fixed PC board **260**. FIG. 3 depicts a perspective view of a side of the panel **160** of the antenna assembly **100** and a back side of the fixed PC board **260**. FIG. 4 is an enlarged detail of FIG. 3. In FIGS. 3 and 4, two similar PC boards **260**, **261** are shown, each having a pair of first and second phase adjusters **200**, **210**. Both pairs operate in the same fashion, and are only illustrated to demonstrate that a plurality of PC boards **260**, **261** may be mounted on a single panel, both being coupled to the same mechanical actuator (rod **500** and main arm **500a**). As discussed above, the first phase adjuster **200** comprises the fixed PC board **260** with the first arcuate slot **255** cut through and the first rotatable PC board or wiper **250** (FIG. 2) on the other side of the fixed PC board **260**. The second phase adjuster **210** comprises the fixed PC board **260**, the second rotatable PC board or wiper **350** (FIG. 2), and the second arcuate slot **485**. To cause the first and second rotatable PC boards **250**, **350** to rotate, the main arm **500a** is coupled to the rotatable PC boards **250**, **350**.

In one embodiment, the mechanical actuator comprises an actuator rod **500**, main arm **500a** and a linkage comprising a first arm **510**, and a second arm **520**. The main arm **500a** is connected to one end of the first arm **510** at a pivot point **511**. The other end of the first arm **510** is connected to the fixed PC board **260** and the first rotatable PC board **250** at the joint **270**. A cross-section of this joint **270** would show there are three layers all connected, the first rotatable PC board **250**, the fixed PC board **260**, and the first arm **510**. Since the fixed PC board **260** is stationary, the first arm **510** and the first rotatable PC board **250** also remain fixed at the joint **270**. The joint **280** connects the first rotatable PC board **250** to the first arm **510** through the first slot **255** on the fixed PC board **260**.

The second arm **520** is connected to the second rotatable PC board **350** through the second slot **405** at the joint **395**. Thus, a movement of the second arm **520** causes the second rotatable PC board **350** to move along the second slot **405**. The second arm **520** is also rotatably connected at a joint **522** to approximately midway between joint **270** and joint **280** on the first arm **510**. Thus, as the first arm **510** is moved, the second arm **520** also moves. Since the second arm **520** is linked to the first arm **510** at the midpoint, as the joint **512** of the first arm **510** moves a predetermined distance, the joint **395** of the second arm **520** moves approximately half the predetermined distance. In other embodiments, the second arm **520** may be attached at different locations over the first arm **510**, depending upon the desired ratio of movement between the first and second phase adjusters **200**, **210**.

FIG. 5 illustrates a grasping end **505** of the actuator rod **500** that extends out past a bottom **530** of the panel **160**. The grasping end **505** of the actuator rod **500** is mounted on the bottom **530** of the panel **160**. By extending the actuator rod **500** out through the bottom **530** of the panel **160**, a person manually adjusting the mechanism only has to pull or push on the actuator rod **500**, instead of having to rotate a small knob or disc located on the side of the panel **160**, as done in the prior art. Also included on the grasping end **505** of the actuator rod **500** are markings **535** to indicate the amount of adjustment made by a person adjusting the mechanism, and a knob **536** is shown covering a threaded end **538** of the actuator rod **500**. The markings **535** have a direct relationship to the vertical downtilt angle of the beam. For example, a zero marking on the rod correlates to a zero degree downtilt angle. Since the markings **535** are not detented, a user may adjust the downtilt angle as much or as little as needed. The downtilt angle need not be moved in degree or half degree increments. The knob **536** screws onto the threaded end **538** and enables the user to easily grasp the actuator rod **500** for movement purposes.

The actuator rod **500** is mounted onto the bottom **530** of the panel **160** by a bushing mount **540**. The bushing mount **540** is best illustrated in FIGS. *6a–6c*. The bushing mount **540** comprises a pair of brackets **550***a*, **550***b* which are attached to the panel **160**. In the embodiment shown, the brackets **550***a*, **550***b* are attached via a pair of screws **560***a*, **560***b* (shown in FIG. 5). It is also contemplated, however, that other methods, such as rivets, adhesive heat staking, welding, and brazing, may be utilized.

The bushing mount **540** also has a cylindrical portion **560** adapted to receive the actuator rod **500**. The cylindrical portion **560** of the bushing mount **540** allows the actuator rod **500** to be slid up and down, enabling movement. To prevent the actuator rod **500** from rotating within the cylindrical portion **560**, however, a flat section **570** (FIG. *6b*) is included on the inner wall of the cylindrical portion **560**. One end of the cylindrical portion **560** includes a threaded portion **565** which will be described in more detail below.

As mentioned above, the grasping end **505** of the actuator rod **500** includes markings **535**. The bushing mount **540** includes an indicator window **590** on opposite sides of the cylindrical portion **560** to enable a user to see the markings **535** (seen in FIG. *6c*). Also, in one embodiment, the bushing mount **540** may be clear plastic so that all of the markings **535** are visible to the user.

As shown in FIGS. 7 and 8, a compression nut **595** is also slid over the actuator rod **500**. The compression nut **595** includes three parts, a threaded nut **600**, a plastic gripper **610**, and a ferrule **620**. The threaded nut **600** of the compression nut **595** screws over the threaded portion **565** of the bushing mount **540** and acts to lock the actuator rod **500** in place. When the threaded nut **600** is being screwed over the threaded portion **565** of the bushing mount **540**, the plastic gripper **610** and the ferrule **620** are sandwiched against the bushing mount **540**. The ferrule acts as a seal against the bushing mount **540**. The plastic gripper **610** contains a slit **625**, which decreases in width as the threaded nut **600** is tightened against the bushing mount **540**. This causes the compression nut **595** to grip the bushing mount **540**, and lock the actuator rod **500** in place.

Although it is useful to have a manual actuator, it may be more desirable to have an electrical actuator that may be controlled from the ground or even remotely, for example, from a control room **630** (FIG. 8A). In FIG. 9, converting the manual actuator described above into an electrical actuator **660** is illustrated. The electrical actuator **660** comprises a piston (not shown) and a threaded barrel **670**. To convert the manual actuator, the compression nut **595** and the knob **536** must first be removed. Then, a lock nut **650** is threaded onto the bushing mount **540**. The threaded end **538** of the actuator rod **500** is threaded into the piston. The barrel **670** of the electrical actuator **660** is then pushed up towards the threaded portion **565** of the bushing mount **540** and threaded. Once both the piston and the threaded barrel are completely threaded onto the actuator rod **500**, the lock nut **650** is tightened, locking the bushing mount **540** to the threaded barrel **670**.

The electrical actuator **660** may be a step motor in a fixed position relative to the panel **160**. The step motor rotates, driving a screw or shaft in a linear motion. The screw or shaft is coupled to the actuator rod **500** and, thus, moves the actuator rod **500** up and down, depending on the rotation of the step motor. It is also contemplated that the electrical actuator **660** may include a receiver **700** adapted to receive adjustment signals from a remote source **702**. A sensor **704** adapted to sense the position of the actuator rod **500** may also be included. A transponder **706** may also be included to return a signal to the remote location or to a signal box which indicates the amount of adjustment made.

The present invention may, thus, be easily converted from a manual actuator to an electrical actuator depending on the needs and wishes of the user. The actuator, thus provides flexibility in use, allowing a user to purchase a manual actuator and then upgrade to an electrical actuator at a later date. The advantages to this are many. The user may not initially wish to expend the money to pay for an electrical actuator if there is rarely a need to adjust the vertical beam. As that need changes, however, the user may purchase the electrical actuator and easily convert the actuator.

While the present invention has been described with reference to one or more particular embodiments, those skilled in the art will recognize that many changes may be made thereto without departing from the spirit and scope of the present invention. Each of these embodiments and obvious variations thereof is contemplated as falling within the spirit and scope of the claimed invention, which is set forth in the following claims.

What is claimed is:

1. A cellular base station antenna system configured to produce a beam of fixed elevation, comprising:
   - an elongated panel antenna system adapted to mount a plurality of spaced radiators;
   - a printed circuit board having conductive traces including a transmission line interconnecting at least selected ones of said radiators; and
   - an electromechanical phase adjustment system including a phase adjuster connected to a signal feed coupled to said transmission line, said phase adjuster having at least one component intermittently moveable by an electrical actuator responsive to commands from a remote signal source to adjust the relative signal phasing of said interconnected radiators between different phase values, and thereby adjust the fixed elevation of the beam, said electrical actuator being positioned at an edge of said panel antenna and coupled to said moveable component of the phase shifter by a mechanical actuator extending lengthwise of said panel antenna, said electrical actuator having a receiver and transponder for communicating wirelessly with said remote source.

2. The antenna system defined by claim 1 wherein said moveable component is an arcuately moveable wiper capacitively coupled to said transmission line, said wiper comprising a conductive trace on an insulated substrate.

3. The antenna system defined by claim 1 including a sensor for sensing the position of said phase adjuster.

4. The antenna system defined by claim 3 wherein said remote signal source is responsive to said sensor.

5. The antenna system defined by claim 3 wherein said sensor senses a position of said mechanical actuator.

6. The antenna system defined by claim 5 wherein said remote signal source is responsive to said sensor.

7. A cellular base station antenna system comprising:

an elongated panel adapted to be installed vertically and to mount a plurality of longitudinally spaced radiators;

a signal feed network operatively coupled to said radiators;

a signal phase adjuster in said feed network; and

a linearly reciprocable, phase-adjustment mechanical actuator coupled to said phase adjuster and having a terminus located near a lower edge of said panel.

8. The system defined by claim 7 wherein said signal phase adjuster includes a pivotally mounted, phase-adjusting wiper capacitively coupled in said feed network.

9. The system defined by claim 8 wherein said mechanical actuator is coupled to said wiper and is configured to convert linear motion of said mechanical actuator to arcuate motion of said wiper.

10. The system defined by claim 8 further including a first printed circuit board which includes at least a portion of said feed network, and wherein said wiper is pivotally mounted on said first printed circuit board.

11. The system defined by claim 10 wherein said wiper comprises a second printed circuit board metallized on one side.

12. The system defined by claim 7 wherein said mechanical actuator terminus extends below a lower edge of said panel.

13. The system defined by claim 7 wherein said mechanical actuator is adapted for conversion between manual manipulation and manipulation by an electrical actuator.

14. The system defined by claim 7 further including a first printed circuit board which includes at least a portion of said feed network.

15. The system defined by claim 14 further including a power divider on said first printed circuit board.

16. The system defined by claim 7 wherein said antenna system includes first and second phase adjusters coupled to and manipulated by said mechanical actuator.

17. The system defined by claim 16 wherein said first and second phase adjusters are mechanically coupled.

18. The system defined by claim 17 wherein said second phase shifter is rotatably linked to said first phase adjuster.

19. The system defined by claim 16 wherein adjustment of said first phase adjuster simultaneously adjusts said second phase adjuster.

20. The system defined by claim 7 wherein said mechanical actuator has indicia providing an indication of a beam downtilt angle.

21. The system defined by claim 7 wherein said mechanical actuator includes a position lock.

22. The system defined by claim 7 wherein said phase adjuster further includes

a fixed printed circuit board;

a signal input mounted on said fixed printed circuit board;

a wiper electromagnetically coupled to said signal input; and

a transmission line electromagnetically coupled to said wiper and formed of a portion of said signal feed network, wherein a movement of said wiper changes an effective length of said transmission line.

23. The system defined by claim 22 wherein said wiper is pivotally coupled to said signal input.

24. The system defined by claim 22 wherein said wiper is a rotatable printed circuit board.

25. The system defined by claim 24 wherein a portion of said transmission line is arcuate in shape.

26. The system defined by claim 25 wherein said wiper further includes an arcuate section having a radius of curvature substantially equal to a radius of curvature of said transmission line, such that as said wiper is pivoted over said transmission line, said wiper remains substantially in alignment with said transmission line.

27. The system defined by claim 7 wherein said mechanical actuator is coupled to and mechanically adjusted by an electrical actuator responsive to commands from a remote signal source.

28. The system defined by claim 27 wherein said electrical actuator includes a receiver and a transponder for communicating wirelessly with said remote signal source.

29. The system defined by claim 28 wherein said electrical actuator includes a sensor for sensing the position of said mechanical actuator and thereby beam elevation.

30. A cellular base station antenna system comprising:

a panel antenna adapted to mount a plurality of radiators;

a signal feed network operatively coupled to said radiators;

at least one mechanical phase adjuster located on said panel and forming a portion of said signal feed network, said phase adjuster having relatively displaceable phase-adjusting components; and

an electrical actuator supported by and positioned off said panel antenna, said electrical actuator being mechanically coupled to at least one of said phase adjusting components.

31. The antenna system defined by claim 30 wherein said electrical actuator is coupled to at least one of said phase adjusting components by a mechanical actuator.

32. The antenna system defined by claim 31 wherein linear motion of said mechanical actuator causes rotational movement of said phase adjusting component.

33. The antenna system defined by claim 31 wherein said mechanical actuator is adapted for conversion to manual manipulation.

34. The antenna system defined by claim 31 including a sensor for sensing a position of said mechanical actuator.

35. The antenna system defined by claim 34 wherein said electrical actuator is controlled by a remotely located signal source which is responsive to said sensor.

36. The antenna system defined by claim 30 wherein said panel antenna is oriented vertically, and wherein said electrical actuator is located below said panel.

37. The antenna system defined by claim 30 wherein said electrical actuator is controlled by a remotely located signal source.

38. The antenna system defined by claim 37 wherein said electrical actuator is configured to be controlled wirelessly.

39. The antenna system defined by claim 30 wherein said panel antenna includes a first printed circuit board which includes at least a portion of said signal feed network.

40. The antenna system defined by claim 39 further including a rotatable wiper mounted on said first printed circuit board, said wiper defining a relatively displaceable phase adjusting component.

41. The antenna system defined by claim 40 wherein said wiper includes a second printed circuit board metallized on one side.

42. The antenna system defined by claim 30 wherein said panel antenna includes a plurality of phase adjusters coupled to and manipulated by a common mechanical actuator.

43. The antenna system defied by claim 30 wherein said electrical actuator includes an electrical motor.

44. A cellular base station antenna system producing a beam of fixed elevation, comprising:

a panel antenna adapted to mount a plurality of radiators;

a transmission line interconnecting said radiators; and

a phase adjustment system for varying a relative phasing of said interconnected radiators, said phase adjustment system further including

a printed circuit board having a printed conductor forming a portion of said transmission line; and

a phase adjuster connected to a signal feed and coupled to said printed conductor, said phase adjuster having an intermittently moveable component configured to adjust a relative signal phasing of said interconnected radiators between different phase values, and thereby to adjust the fixed beam elevation, said phase adjuster system being mechanically manipulated by an electrical actuator responsive to commands from a remote signal source.

45. The antenna system defined by claim 44 further including a moveable printed circuit board pivotally connected to said printed circuit board and having a conductive layer capacitively coupled to said printed conductor.

46. The antenna system defined by claim 44 further including a power divider printed on said printed circuit board between said signal feed and said phase adjuster.

47. The antenna system assembly defined by 44 further including a mechanical actuator connected between said phase adjuster and said electrical actuator.

48. An antenna system producing a beam having an adjustable elevation, comprising:

a panel antenna adapted to mount a plurality of radiators;

a signal feed operatively coupled to said radiators;

at least one mechanical phase adjuster located on said panel antenna, said phase adjuster having relatively displaceable phase-adjusting components;

an electrical actuator positioned near the edge of said panel, said electrical actuator being mechanically coupled to said phase adjuster by a mechanical actuator; and

said system providing indicia indicating by the physical position of the actuator, the elevation of the beam.

49. A cellular base station antenna system comprising:

a panel antenna adapted to mount a plurality of radiators;

printed circuit board means;

a network of transmission lines connecting a signal feed to each of said radiators, each of said transmission lines including a printed conductor trace on said printed circuit board means, said traces having differing trace lengths to alter a default phasing of said radiators; and

a power divider printed on said printed circuit board means between said feed and said network.

50. The antenna system defined by claim 49 wherein said network of transmission lines includes a plurality of coaxial cables of equal length.

51. A cellular base station antenna system adapted both for manual adjustment of fixed beam elevation and for retrofitting of an electrical actuator for electrical adjustment of beam elevation, comprising:

a panel antenna adapted to mount a plurality of spaced radiators;

a signal feed network operatively coupled to said radiators;

a signal phase adjuster in said feed network; and

a phase-adjustment mechanical actuator coupled to said phase adjuster, said mechanical actuator being configured first for manual adjustment of beam elevation and second for selective attachment of an electrical actuator for remote electrical adjustment of beam elevation.

52. The system defined by claim 51 wherein said mechanical actuator has a terminus below an edge of said panel antenna, said terminus being configured for manual adjustment of beam elevation, and for attachment of said electrical actuator.

53. The system defined by claim 52 wherein said terminus includes a threaded nut with an opening which passes an elongated member extending to said phase shifter and driven by said electrical actuator.

54. The system defined by claim 53 wherein said elongated member contains indicia which indicates beam elevation based upon the position of the elongated member.

55. The system defined by claim 51 including a plurality of spaced phase shifters, and wherein said mechanical actuator includes an elongated member which extends lengthwise along said panel antenna and is coupled to said phase shifters for simultaneous manual or electrical manipulation of each of them.

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(54) ANTENNA CONTROL SYSTEM

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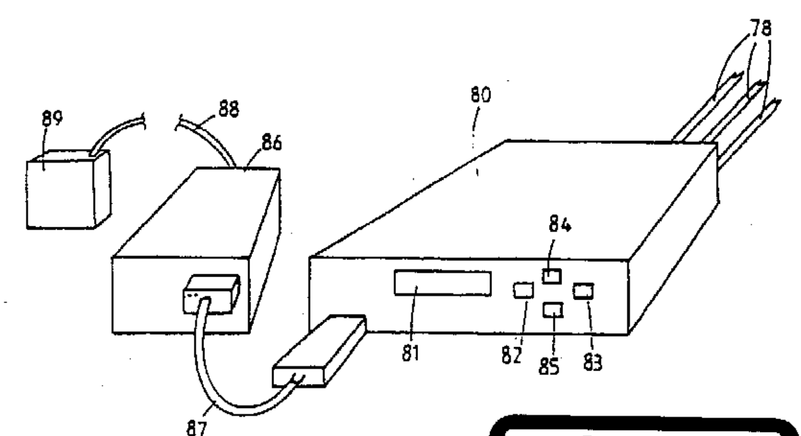
(57) **ABSTRACT**

An antenna control system enabling the remote variation of antenna beam tilt. A drive means continuously adjusts phase shifters of a feed distribution network to radiating elements to continuously vary antenna beam tilt. A controller enables the beam tilt of a number of antenna at a site to be remotely varied.

90 Claims, 8 Drawing Sheets



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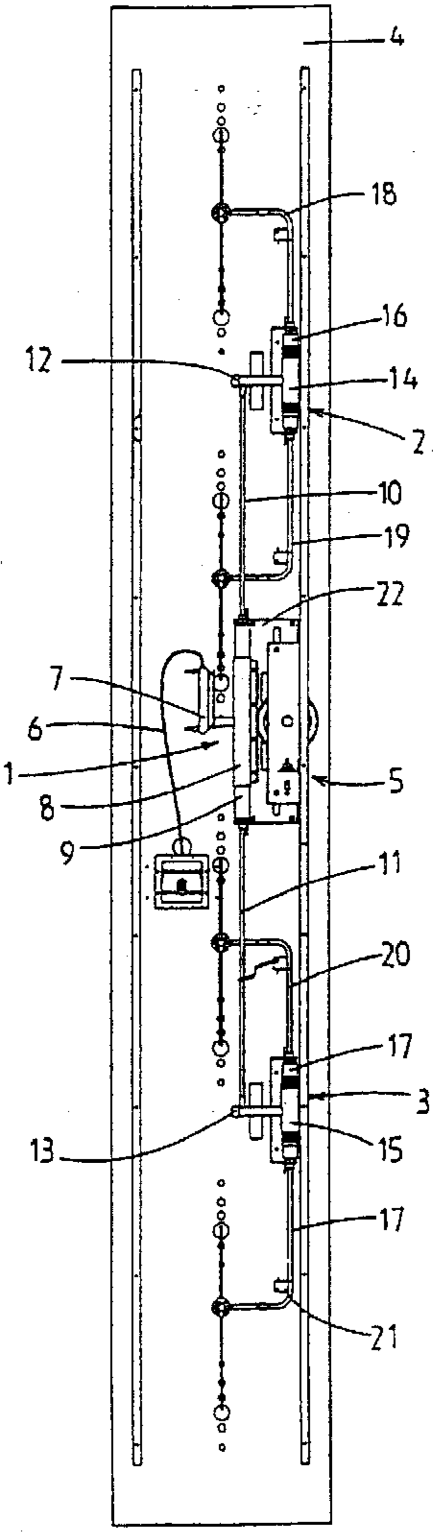

FIG.1

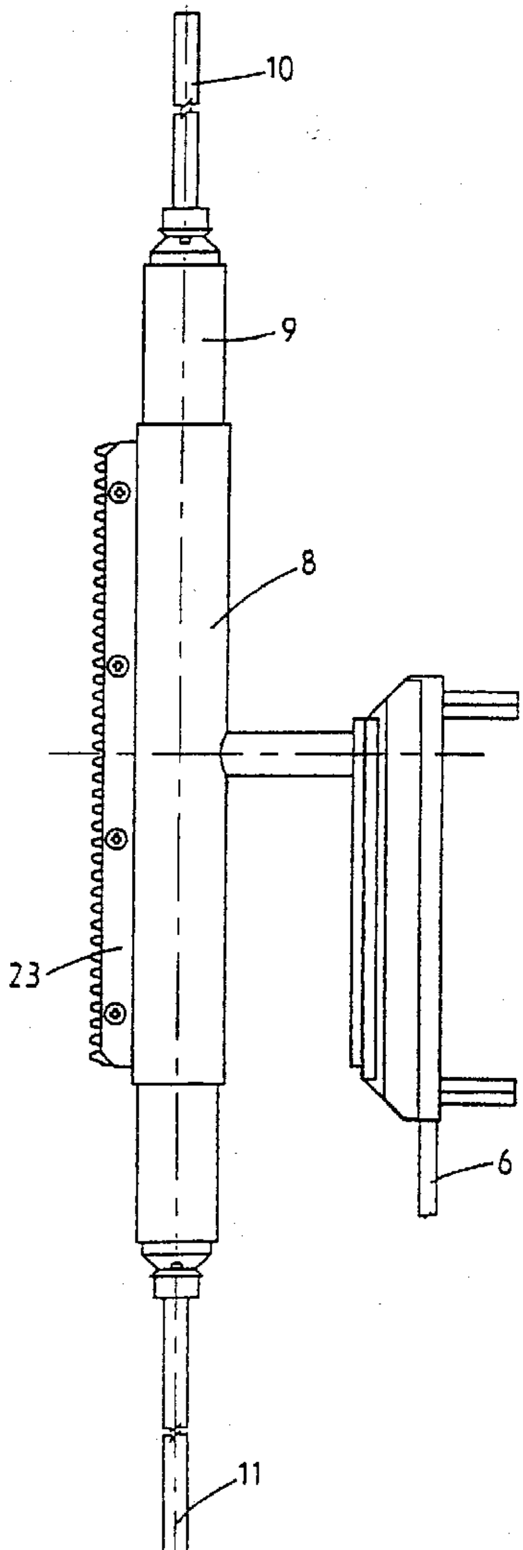

FIG. 2

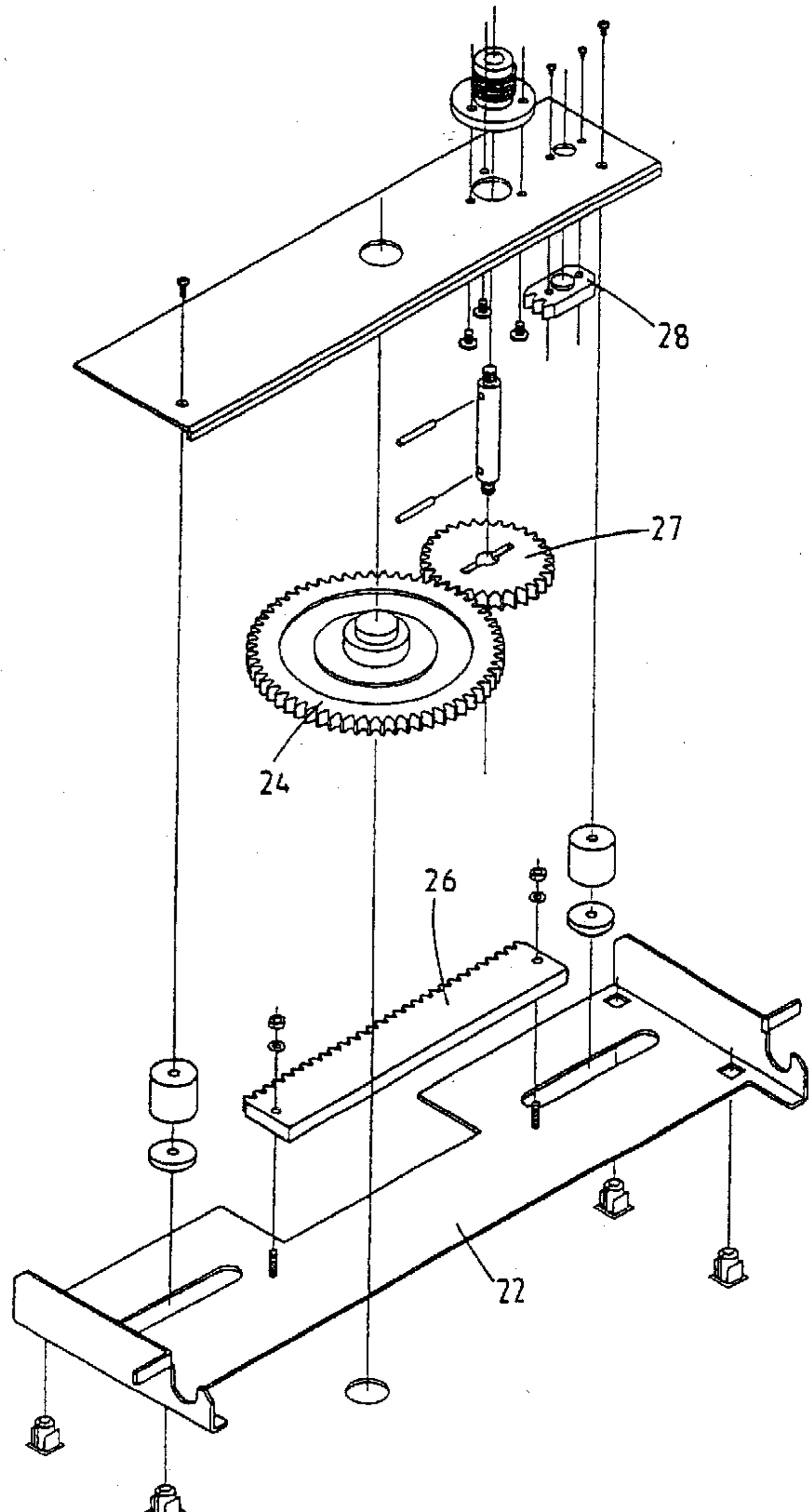

FIG. 3

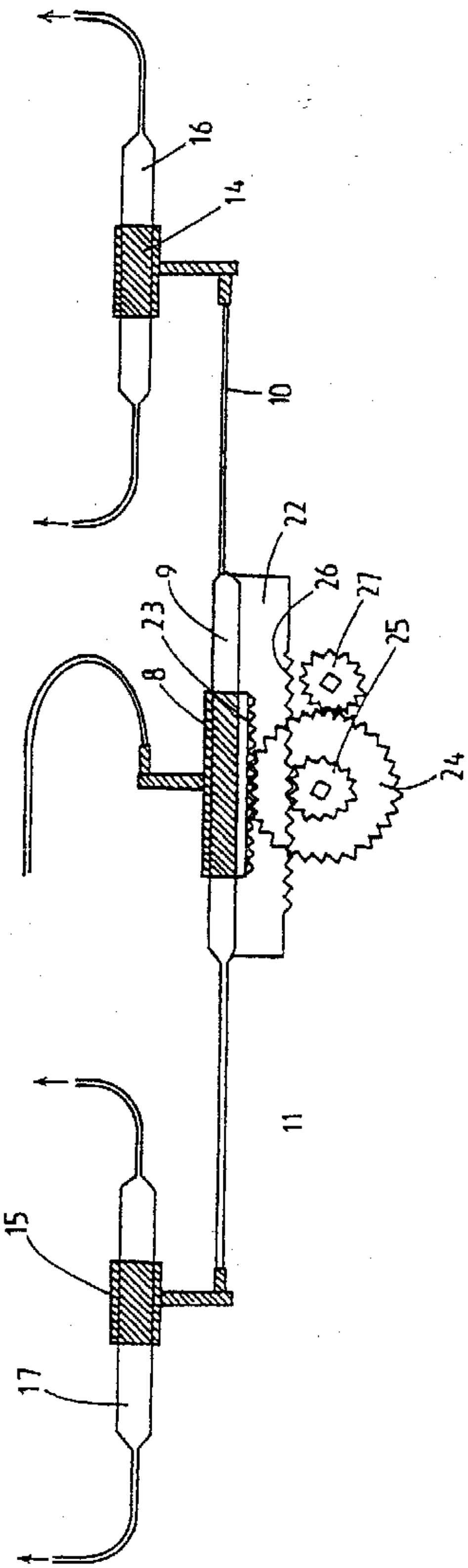

FIG.4

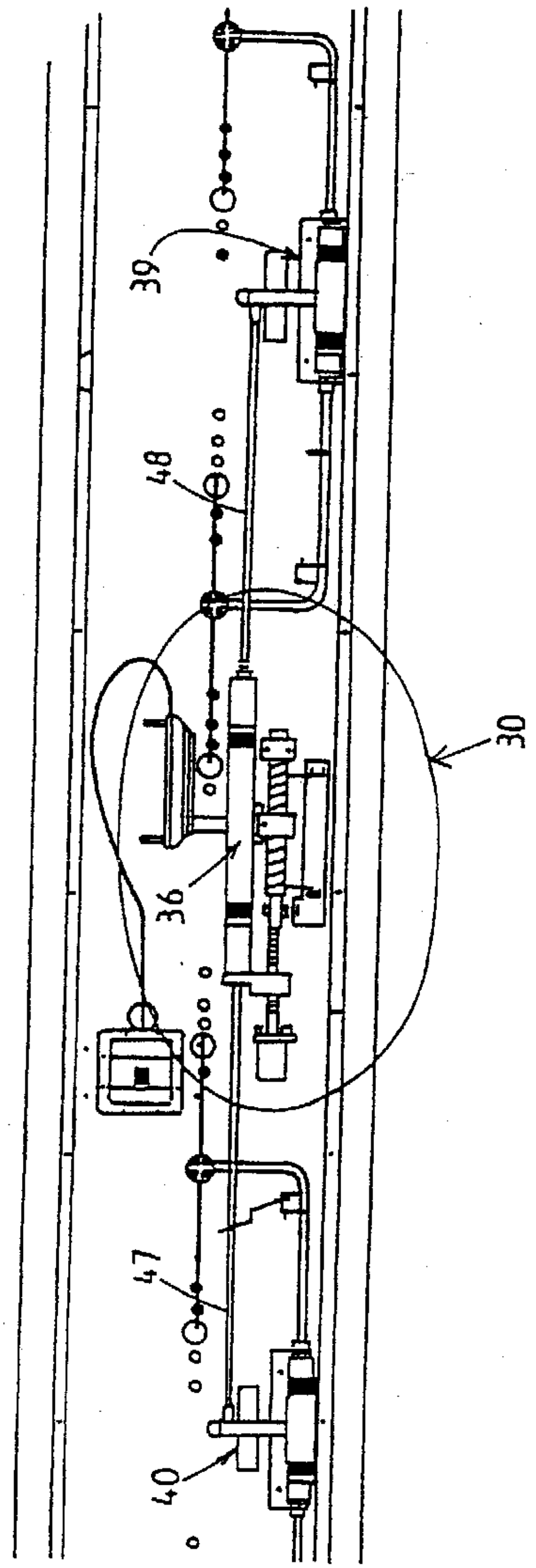

FIG. 5

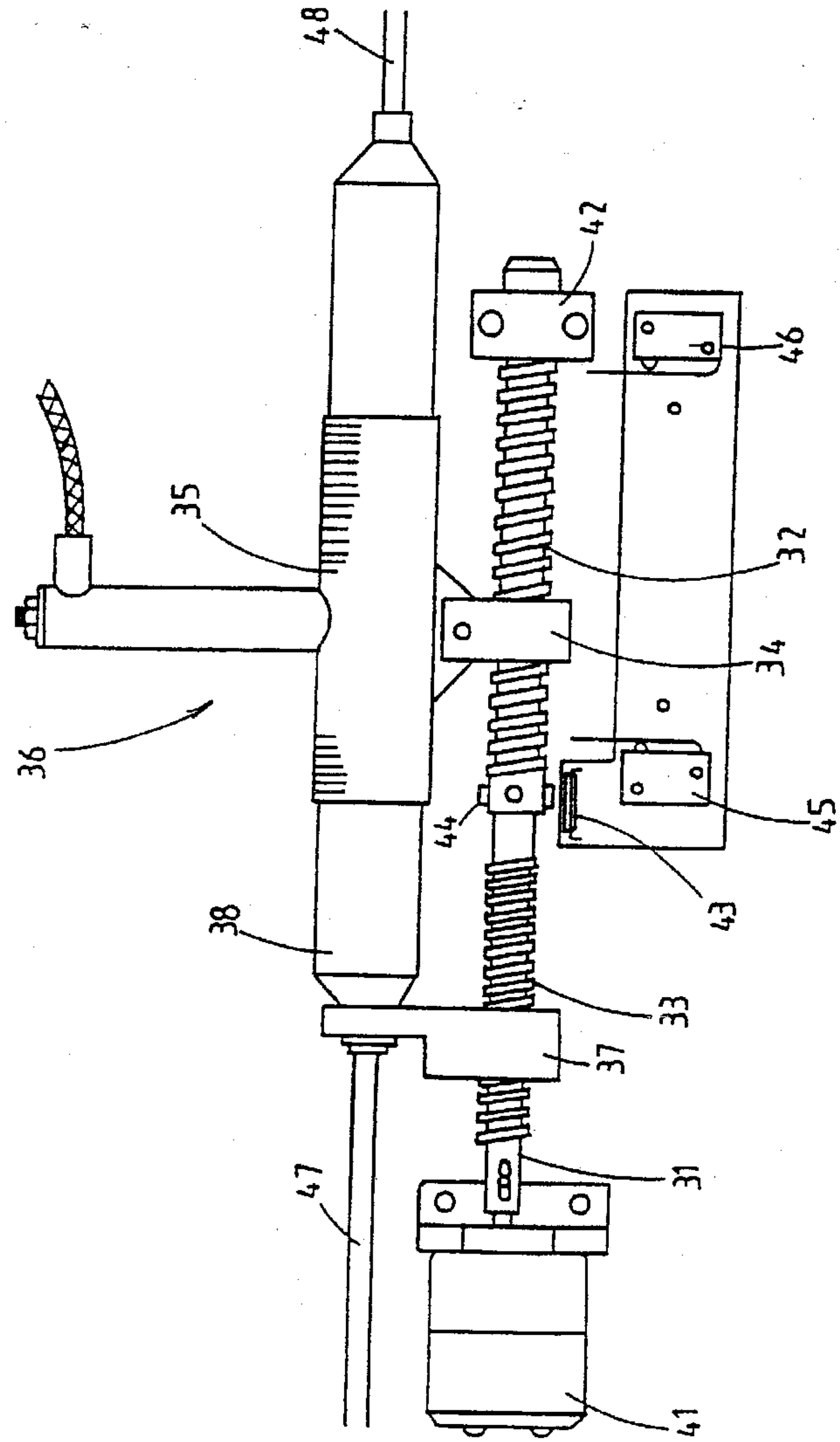

FIG. 6

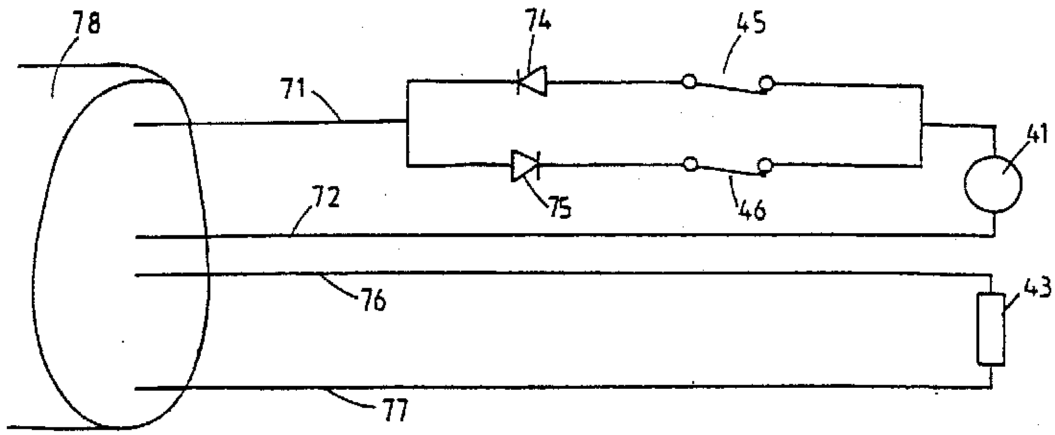

FIG. 7

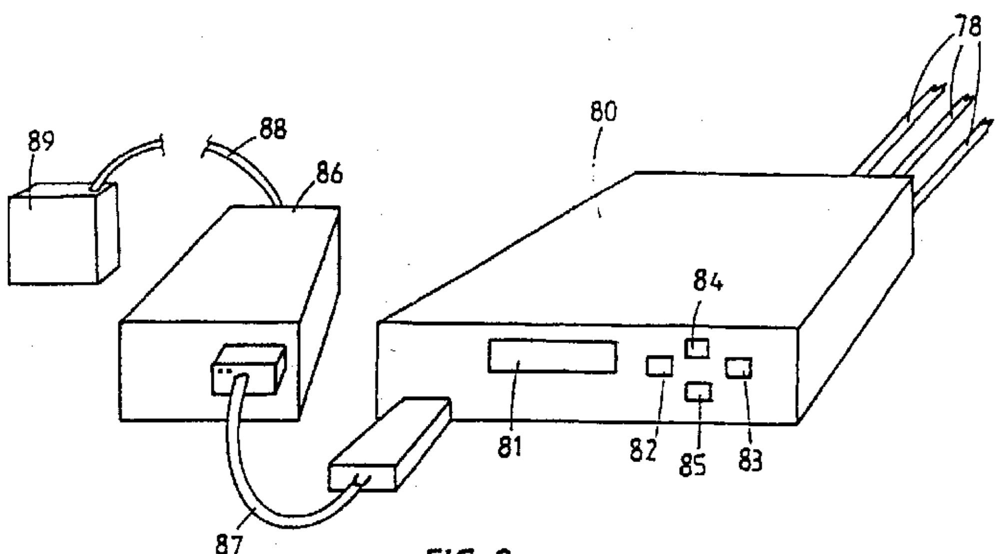

FIG. 8

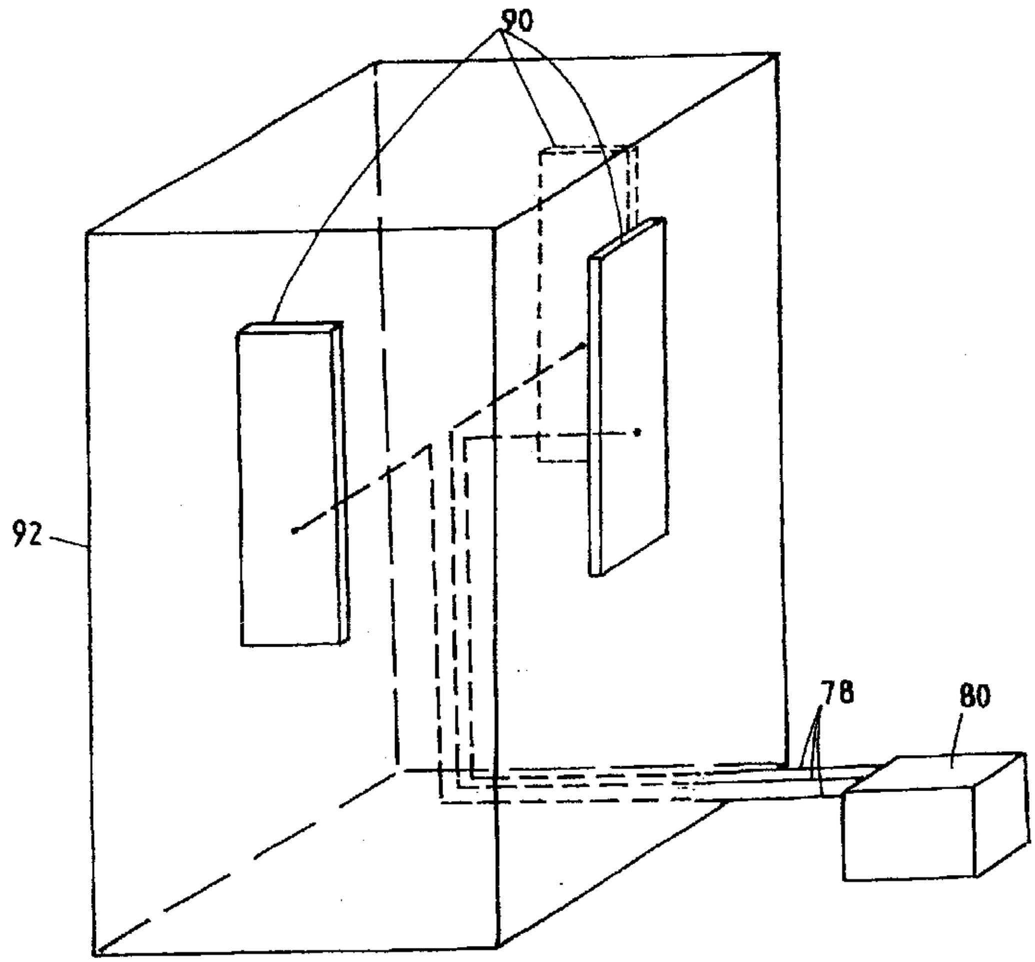

FIG. 9

ANTENNA CONTROL SYSTEM

This is a continuation of application Ser. No. 10/073,468, filed Feb. 11, 2002, which is a continuation of application Ser. No. 09/713,614, filed Nov. 15, 2000, now U.S. Pat. No. 6,346,924, which is a continuation of application Ser. No. 08/817,445, filed Apr. 30, 1997, now U.S. Pat. No. 6,198,458 B1, all of which are entitled Antenna Control System.

THE TECHNICAL FIELD

The present invention relates to an antenna control system for varying the beam tilt of one or more antenna. More particularly, although not exclusively, the present invention relates to a drive system for use in an antenna which incorporates one or more phase shifter.

BACKGROUND OF THE INVENTION

In order to produce downtilt in the beam produced by an antenna array (for example a panel antenna) it is possible to either mechanically tilt the panel antenna or electrically steer the beam radiated from the panel antenna according to techniques known in the art.

Panel antennas, such as those to which the present application is concerned, are often located on the sides of buildings or similar structures. Mechanical tilting of the antenna away from the side of the building increases the susceptibility of the installation to wind induced vibration and can impact on the visual environment in situations where significant amounts of downtilt are required.

In order to avoid the above difficulties, electrical beam steering can be effected by introducing phase delays into the signal input into radiating elements or groups of radiating elements in an antenna array.

Such techniques are described in New Zealand Patent Specification No. 235010.

Various phase delay techniques are known, including inserting variable length delay lines into the network feeding to the radiating element or elements, or using PIN diodes to vary the phase of a signal transmitted through the feeder network.

A further means for varying the phase of two signals is described in PCT/NZ94/00107 whose disclosure is incorporated herein by reference. This specification describes a mechanically operated variable differential phase shifter incorporating one input and two outputs.

For the present purposes it is sufficient to note that phase shifters such as those described in PCT/NZ94/00107 are adjusted mechanically by sliding an external sleeve along the body of the phase shifter which alters the relative phase of the signals at the phase shifter outputs.

A typical panel antenna will incorporate one or more phase shifters and the present particular embodiment includes three phase shifters. A signal is input to the primary phase shifter which splits the signal into two signals having a desired phase relationship. Each phase shifted signal is then input into a secondary phase shifter whose outputs feeds at least one radiating element. In this manner a progressive phase shift can be achieved across the entire radiating element array, thus providing a means for electrically adjusting the downtilt of the radiated beam. Other phase distributions are possible depending on the application and shape of the radiated beam.

While the steering action is discussed in the context of downtilt of the radiated beam, it is to be understood that the present detailed description is not limited to such a direction. Beam tilt may be produced in any desired direction.

Another particular feature of the variable differential phase shifters is that they provide a continuous phase adjustment, in contrast with the more conventional stepped phase adjustments normally found in PIN diode or stepped length delay line phase shifters.

In a panel antenna of the type presently under consideration, it is desirable to adjust the entire phase shifter array simultaneously so that a desired degree of beam tilt may be set by the adjustment of a single mechanical setting means. The mechanical drive which performs such an adjustment must result in reproducible downtilt angles and be able to be adapted to provide for a number of different phase shifter array configurations.

It is also desirable that the beam tilt of an antenna may be varied remotely to avoid the need for personnel to climb a structure to adjust antenna beam tilt.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a mechanical drive system for use in adjusting mechanical phase shifters which mitigates the above mentioned difficulties, provides a solution to the design requirements of the antennas or antenna arrays described above, or at least provides the public with a useful choice.

Accordingly, there is provided a mechanical adjustment means for adjusting the relative phase shifts produced by a plurality of phase shifters connected to an array of radiating elements, said mechanical adjustment means including:

- first means for moving a first portion of a first phase shifter relative to a second portion of said first phase shifter to vary the phase difference between output signals from the first phase shifter; and
- second means for moving a first portion of a second phase shifter relative to a second portion of said second phase shifter to vary the phase difference between output signals from the second phase shifter, wherein the second phase shifter is fed from an output of the first phase shifter and the degree of movement of the second means is dependent upon the degree of movement of the first means.

Preferably, movement of the second means results in simultaneous movement of a first portion of a third phase shifter with respect to a second portion of the third phase shifter wherein the third phase shifter is fed from an output of the first phase shifter.

Preferably the outputs of the second and third phase shifters are connected to radiating elements so as to produce a beam which tilts as the first and second means adjusts the phase shifters.

Preferably the movement of the first portion of the first phase shifter a first distance relative to the second portion of the first phase shifter results in relative movement between first portions of the second and third phase shifters relative to second portions of the second and third phase shifters of about twice the first distance.

According to a first preferred embodiment the first means includes a gear wheel which drives a rack connected to a first portion of the first phase shifter, arranged so that rotation of the first gear wheel causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter. Preferably, the second portion of the first phase shifter is mounted to a carriage and the outputs of the first phase shifter are connected to inputs of the second and third phase shifters by push rods so that movement of the second portion of the first phase shifter moves the first portions of the second and third phase shifters with respect to the second portions of the second and third phase shifters.

Preferably a second gear is provided co-axial with and connected to a shaft driving the first gear which drives a rack connected to the second part of the first phase shifter so that rotation of the second gear causes movement of the first portion of the second and third phase shifters relative to the second portions of the second and third phase shifters.

Preferably the ratio between the first and second gear wheels is about 3:1.

According to a second embodiment of the present invention the adjustment means includes a shaft and said first means includes a first threaded portion provided on said shaft and a first cooperating threaded member connected to the first portion of the first phase shifter. The second means includes a second threaded portion provided on said shaft and a second cooperating threaded member connected to the first portion of the second phase shifter. The arrangement is such that rotation of the shaft causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter at a rate of about twice that of the movement of the first portion of the second phase shifter relative to the second portion of the second phase shifter.

Preferably the second threaded member is connected to the second portion of the first phase shifter and moves the first portion of the second phase shifter via a push rod. This push rod is preferably a coaxial line connecting an output from the first phase shifter to the input to the second phase shifter.

Preferably there is further provided a third phase shifter fed from a second output of the first phase shifter via a push rod which moves a first portion of the third phase shifter in unison with the first portion of the second phase shifter.

According to a further aspect of the invention there is provided an antenna system comprising one or more antenna including electromechanical means for varying the downtilt of the antenna and a controller, external to the antenna, for supplying drive signals to the electromechanical means for adjusting downtilt.

Preferably the system includes a plurality of antennas and the controller may adjust the downtilt for the plurality of antennas and store the degree of downtilt of each antenna in memory.

Preferably the controller may be controlled remotely from a control centre so that a plurality of such systems may be remotely controlled as part of a control strategy for a number of cellular base stations.

Preferably the electromechanical means varies the electrical downtilt of each antenna and means are included for monitoring the electromechanical means and providing signals representative of the position of the electromechanical means to the controller.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1: shows a panel antenna incorporating a phase shifter drive mechanism according to a first embodiment of the invention.

FIG. 2: illustrates a primary phase shifter incorporating a gear rack.

FIG. 3: illustrates an exploded view of the adjustment assembly incorporated into the carriage.

FIG. 4: shows diagrammatically the operation of the drive mechanism according to the first embodiment.

FIG. 5: shows a panel antenna incorporating a phase shifter drive mechanism according to a second embodiment of the invention.

FIG. 6: shows the phase shifter drive mechanism of FIG. 5 in detail.

FIG. 7: shows the electrical connection of the motor, switches and reed switch of the drive mechanism shown in FIG. 6.

FIG. 8: shows a controller for controlling the drive mechanism shown in FIGS. 6 and 7.

FIG. 9 shows an antenna system according to one aspect of the present invention having a plurality of antennas controlled by a controller.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to FIG. 1 there is shown the back side of a panel antenna **4** having a first phase shifter **1**, a second phase shifter **2**, a third phase shifter **3** and a phase shifter drive mechanism **5**. Feed line **6** is connected to input **7** of phase shifter **1**. A first portion **8** of phase shifter **1** is moveable relative to a second portion **9** of phase shifter **1**.

Output signals from phase shifter **1** are supplied via lines **10** and **11** to inputs **12** and **13** of phase shifters **2** and **3** respectively. Feed lines **10** and **11** comprise coaxial push rods which serve the functions both of feeding signals from the outputs of phase shifter **1** to phase shifters **2** and **3** and moving first portions **14** and **15** of phase shifters **2** and **3** relative to second portion **16** and **17** of phase shifters **2** and **3** respectively.

Signals output from phase shifters **2** and **3** are supplied via coaxial lines **18**, **19**, **20** and **21** to be fed to respective radiating elements (not shown).

In use first portion **8** of phase shifter **1** may be moved relative to second portion **9** of phase shifter 1 to change the relative phase of signals supplied via lines **10** and **11** to phase shifters **2** and **3** respectively. First portions 14 and 15 of phase shifters **2** and **3** may be moved relative to second portions 16 and 17 of phase shifters **2** and **3** to vary the phase of signals supplied by lines **18**, **19**, **20** and **21** to respective radiating elements.

When phase shifters **1**, **2** and **3** are adjusted in the correct respective portions the beam emitted by the antenna can be tilted as required. It will be appreciated that where a less defined beam is required fewer phase shifters may be employed.

To achieve even continuous beam tilting for the embodiment shown in FIG. 1 the first portions **14** and **15** of phase shifters **2** and **3** should move relative to the second portion **16** and **17** of phase shifters **2** and **3** at the same rate. The first portion **8** of phase shifter **1** must however move relative to the second portion **9** of phase shifter **1** at twice this rate. In the arrangement shown second portion **9** of phase shifter **1** is connected to carriage **22**. Movement of carriage **22** results in movement of first portions **14** and **15** of phase shifters **2** and **3** via push rods **10** and **11**.

Referring now to FIG. **4**, operation of the phase shifter drive mechanism will be explained. Second portion **9** of phase shifter **1** is mounted to a carriage **22** which can move left and right. If carriage **22** is moved to the left first portions **14** and **15** of phase shifters **2** and **3** will be moved to the left via push rods **10** and **11**. First portion **8** of phase shifter **1** may be moved relative to second portion **9** of phase shifter **1** to vary the phase of signal supplied to phase shifters **2** and **3**.

According to this first embodiment a rack **23** is secured to first portion **8** of phase shifter **1**. Upon rotation of gear wheel **24** first portion **8** of phase shifter **1** may be moved to the left or the right. A smaller gear wheel **25** is secured to and rotates with gear wheel **24**. This gear wheel engages with a rack **26** provided on carriage **22**. A further gear wheel **27** is provided which may be driven to rotate gear wheels **24** and **25** simultaneously.

Gear wheel **24** has 90 teeth whereas gear wheel **25** has 30 teeth. It will therefore be appreciated that rotation of gear wheel **24** results in first portion **8** of phase shifter **1** being moved three times as far as carriage **22** (and hence first portions **14** and **15** of phase shifters **2** and **3**). However, as carriage **22** is moving in the same direction as the first portion **8** of phase shifter **1** it will be appreciated that the relative movement between first portion **8** and second portion **9** of phase shifter **1** is twice that of the relative movement between the first and second portions of phase shifters **2** and **3**. Accordingly, this arrangement results in the relative phase shift produced by phase shifter **1** being twice that produced by phase shifters **2** and **3** (as required to produce even beam tilting in a branched feed arrangement).

The particular arrangement is shown in more detail in FIGS. **2** to **4**. It will be appreciated that gear wheel **27** may be driven by any appropriate manual or driven means. Gear wheel **27** may be adjusted by a knob, lever, stepper motor or other driven actuator. A keeper **28** may be secured in place to prevent movement once the desired settings of the phase shifters have been achieved.

Referring now to FIGS. **5** and **6**, a second embodiment will be described. As seen in FIG. **5**, the arrangement is substantially the same as that shown in the first embodiment except for the drive mechanism **30** employed, which is shown in FIG. **6**.

In this embodiment the drive mechanism includes a shaft **31** having a first threaded portion **32** and a second threaded portion **33** provided thereon. A first threaded member **34** is connected to a first portion **35** of primary phase shifter **36**. A second threaded member **37** is connected to the second portion **38** of primary phase shifter **36**.

First threaded portion **32** is of three times the pitch of second threaded portion **33** (e.g. the pitch of the first threaded portion **32** is 6 mm whereas the pitch of the second threaded portion is 2 mm). In this way, first portion **35** is driven in the direction of movement at three times that of second portion **38**. In this way the phase shift produced by primary phase shifter **36** is twice that of second and third phase shifters **39** and **40**.

Shaft **31** is rotated by motor **41**. This may suitably be a geared down 12 volt DC motor. The other end of shaft **31** is supported by end bearing **42**. A reed switch **43** is provided to detect when magnets **44** pass thereby. In this way the number of rotations of shaft **31** may be monitored. Limit switches **45** and **46** may be provided so that the motor is prevented from further driving shaft **31** in a given direction if threaded member **34** abuts a lever of limit switch **45** or **46** respectively.

Operation of the drive means according to the second embodiment will now be described by way of example. Motor **41** may rotate shaft **31** in an anticlockwise direction, viewed from right to left along shaft **31**. Threaded member **37** is driven by second threaded portion **33** to move push rods **47** and **48** to the left, and thus to adjust phase shifters **39** and **40**.

Threaded member **34** is driven to the left at three times the rate of threaded member **37**. First portion **35** thus moves to the left at three times the rate of second portion **38**. First portion **35** therefore moves relative to second portion **38** at twice the speed the first portions of phase shifters **39** and **40** move relative to their respective second portions. In this way, delays are introduced in the paths to respective radiating elements so as to produce an evenly tilting beam.

The conductivity of reed switch **43** is monitored so that the number of rotations, or part rotations, of shaft **31** may be monitored. If the motor continues driving shaft **31** until threaded member **34** abuts the lever of limit switch **45** then logic circuitry will only permit motor **41** to drive in the opposite direction. Likewise if threaded member **34** abuts the lever of limit switch **46** the motor **41** will only be permitted to drive in the opposite direction.

It will be appreciated that the techniques of both embodiments could be employed in antenna arrays using a larger number of phase shifters. In such applications the relative movement of the first portion of each phase shifter relative to the second portion of each phase shifter would decreased by a factor of 2 for each successive phase shifter along each branch. The ratios used may be varied if the radiation pattern of the antenna needs to be altered to account for the directivity of the individual radiating elements and the effect of the back panel as the amount of downtilt is varied.

Components of the drive mechanism **30** are preferably formed of plastics, where possible, to reduce intermodulation. Threaded members **34** and **37** preferably include plastic links to phase shifter **36** to reduce intermodulation.

It will be appreciated that a number of mechanical drive arrangements may be used to achieve adjustment of the phase shifters in the desired ratio. It is also to be appreciated that sophisticated control electronics may be employed, although the simplicity of construction of the present invention is seen as an advantage.

FIG. **7** shows how motor **41**, reed switch **43** and switches **45** and **46** are connected to lines **71**, **72**, **76** and **77** from an external controller. Lines **71**, **72**, **76** and **77** are sheathed by conduit **78**. Lines **71** and **72** supply current to drive motor **41**. Section **73** ensures that if threaded member **34** is driven to either the left-hand side limit or the right-hand side limit it can only be driven in the opposite direction. In the position shown in FIG. **7**, switch **45** directly connects line **71** to switch **46** via diode **74**. In the position shown switch **46** connects line **71** to motor **41** via diode **75**. This is the normal position of the switches when threaded member **34** is not at either extreme limit. When threaded member **34** is driven to the extreme left, for example, and actuates switch **45**, then switch **45** open circuits the path via diode **74**. Diode **74** allows current flow in the direction allowing motor **41** to drive to the left. Accordingly, when switch **45** is open, motor **41** can only drive in such a direction as to drive threaded member **34** to the right (i.e.: current in the direction allowed by diode **75**).

Likewise, if threaded member **34** is driven to the extreme right, switch **46** is opened to break the path via diode **75**. This prevents motor **41** driving in such a direction as to drive threaded member **34** further to the right.

Lines **76** and **77** are connected to reed switch **43** so that the opening and closing of reed switch **43** may be monitored by an external control unit. In use, the opening and closing of reed switch **43** may be monitored to determine the position of threaded member **34**, and hence the corresponding degree of tilt of the antenna.

To select an initial angle of downtilt threaded member **34** may be driven to the extreme right. An external controller may provide a current in one direction to motor **41** to drive member **34** to the right. The motor will continue to be driven to the right until threaded portion **34** abuts switch **46**. When switch **46** is opened diode **75** will be open circuited, which will prevent the motor being driven further to the right.

The controller will sense that threaded member **34** is at its extreme right position as it will detect that reed switch **43** is not opening and closing. After a predetermined delay the controller may then provide a current in the opposite direction via lines **71** and **72** to motor **41** to drive it to the left. As the motor is driven to the left the controller will monitor the opening and closing of reed switch **43** to determine how far threaded member **34** has moved to the left. The controller will continue to move threaded member **34** to the left until reed switch **43** has opened and closed a predetermined number of times, corresponding to a desired angle of downtilt. Alternatively, threaded member **34** may be driven to the extreme left and then back to the right.

As shown in FIG. 9, at an antenna site a number of such panels **90** may be installed and controlled by a single controller **80** as shown in FIG. 8. The four wires **71, 72, 76,** and **77** correspond to respective cable groups **78** to three such antenna panels. Controller **80** may be provided at the base of an antenna site to allow an operator to adjust the tilt of a plurality of antennas at ground level, rather than requiring a serviceman to climb up the antenna structure **92** and adjust each antenna manually. Alternatively, controller **80** may be a hand-held unit which can be plugged into a connector at the base of an antenna to adjust the antenna at a site.

Controller **80** may include a display **81**, an "escape" button **82**, an "enter" button **83**, an "up" button **84** and "down" button **85**. At power up display **81** may simply display a home menu such as "Deltec NZ Ltd©1995". Upon pressing any key, a base menu may be displayed including options such as:

unlock controls
set array tilt
measure tilt
enable array
disable array
lock controls

The up/down keys may be used to move through the menu and the enter key **83** used to select an option. If "unlock controls" is selected a user will then be required to enter a three digit code. The up/down keys may be used to move through the numbers 0 to 9 and enter used to select each number. If the correct code is entered "locked released" appears. If the incorrect code is entered "controls locked" appears and a user is returned to the home menu. If "set array tilt" is selected from the base menu the following may appear:

set array tilt
array:01 X.X°

The up-down keys **84, 85** may be used to select the desired array number. The enter key accepts the selected array and the previously recorded angle of downtilt may be displayed as follows:

set array tilt
array: 01 4.6°

In this example the previously set angle of downtilt with 4.6°. Using the up/down keys **84,85** a new angle may be entered. Controller **80** may then provide a current to motor **41** via lines **71** and **72** to drive threaded portion **34** in the desired direction to alter the downtilt. The opening and closing of reed switch **43** is monitored so that threaded member **34** is moved in the desired direction for a predetermined number of pulses from reed switch **43**. The downtilt for any other array may be changed in the same manner. If the controller is locked a user may view an angle of downtilt but will not be able to alter the angle.

If the "measure array" option is selected the present angle of downtilt of the antenna may be determined. Upon selecting the "measure tilt" function from the base menu, the following display appears:

measure tilt
array: 01 X.X°.

The up/down buttons may be used to select the desired array. The enter key will accept the selected array. To measure the actual angle of downtilt controller **80** drives a motor **41** of an array to drive member **34** to the right. Motor **41** is driven until threaded member **34** abuts switch **46**. The controller **80** counts the number of pulses from reed switch **43** to determine how far threaded portion **34** has traveled. At the extreme right position the controller **80** determines and displays the angle of downtilt, calculated in accordance with the number of pulses connected from reed switch 43. The controller **80** then drives threaded member **34** back in the opposite direction for the same number of pulses from reed switch **43** so that it returns to the same position. The angle of downtilt for each antenna may be stored in memory of controller **80**. This value will be updated whenever the actual angle of downtilt is measured in this way. The "measure tilt" function may not be used if the controller is locked.

Controller **80** may include tables in memory containing the number of pulses from reed switch **43**, that must be counted for threaded member **34** to achieve each desired degree of downtilt. This may be stored as a table containing the number of pulses for each required degree of downtilt, which may be in 0.1° steps. This approach ensures that any non-linearities of the antenna may be compensated for as the tables will give the actual amount of movement required to achieve a desired downtilt for a given antenna.

The "enable array" function may be used to enable each array when installed. The controller **80** will be prevented from moving any array that has not been enabled. Controller **80** will record in memory which arrays have been enabled. The "disable array" function may be used to disable arrays in a similar manner.

The "lock controls" function may be used to lock the controller once adjustment has been made. A "rack error" signal may be displayed if the array has not operated correctly. This will indicate that an operator should inspect the array.

Adjustment of the array may also be performed remotely. Controller **80** may be connected to modem **86** via serial line **87** which may connect via telephone line **88** to a central controller **89**. Alternatively, the controller **80** may be connected to a central controller **89** via a radio link etc. The functions previously discussed may be effected remotely at central controller **89**. In a computer controlled system adjustments may be made by a computer without operator intervention. In this way, the system can be integrated as part of a control strategy for a cellular base station. For example, a remote control centre **89** may adjust the downtilt of antennas at a cellular base station remotely to adjust the size of the cell in response to traffic demand. It will be appreciated that the capability to continuously and remotely control the electrical downtilt of a number of antenna of a cellular base station may be utilised in a number of control strategies.

Central controller **89** may be a computer, such as an IBM compatible PC running a windows based software program. A main screen of the program may show information regarding the antenna under control as follows:

GROUP 1	NAME	TYPE ANGLE	CURRENT VALUE	NEW	STATUS
antenna 1	1 south	VT01	12°	12.5°	setting
antenna 2	1 north	VT01	12°	12.5°	queued
antenna 3	1 west	VTO1	12°	12.5°	queued

GROUP 2	NAME	TYPE	CURRENT ANGLE	NEW VALUE	STATUS
antenna 4	2 south	VT01	6°		pending
antenna 5	2 north	VT01	6°	.5°	nudging
antenna 6	2 west	VTO1	6°		faulty

The antennas may be arranged in groups at each site. Group 1 for example contains antennas 1, 2 and 3. The following information about each antenna is given:

Name: this is the user assigned name such as 1 south, 1 north, 1 west etc.

Type: this is the antenna type which the controller communicates to the PC at start-up.

Current Angle: this is the actual degree of beam tilt of an antenna which is communicated from the controller to the PC at start-up. The controller also supplies to the PC each antenna's minimum and maximum angles of tilt.

New Value: by moving a pointer to the row of an antenna and clicking a button of a mouse the settings of an antenna may be varied. When a user clicks on the mouse the following options may be selected:

Name—the user may change the group or antenna name.

Adjust—a user may enter a new angle in the "new value" column to set the antenna to a new value.

Nudge—the user may enter a relative value (i.e.: increase or decrease the tilt of an antenna by a predetermined amount).

Measure—the controller may be instructed to measure the actual angle of tilt of an antenna or group of antennas.

If an antenna is in a "fault" condition then it may not be adjusted and if a user clicks on a mouse when that antenna is highlighted a dialogue box will appear instructing the user to clear the fault before adjusting the antenna.

Each antenna also includes a field indicating the status of the antenna as follows:

O.K.—the antenna is functioning normally.

Queued—an instruction to read, measure, set or nudge the antenna has been queued until the controller is ready.

Reading—when information about an antenna is being read from the controller.

Measuring—when the actual degree of tilt of the antenna is being measured.

Setting—when a new tilt angle is being set.

Nudging—when the tilt angle of the antenna is being nudged.

Faulty—where an antenna is faulty.

When adjusting, measuring or nudging an antenna a further dialogue box may appear describing the action that has been instructed and asking a user to confirm that the action should be taken. This safeguards against undesired commands being carried out.

Information for a site may be stored in a file which can be recalled when the antenna is to be monitored or adjusted again. It will be appreciated that the software may be modified for any required control application.

Controller **80** may be a fixed controller installed in the base of an antenna site or could be a portable control unit which is plugged into connectors from control lines **78**.

Where in the foregoing description reference has been made to integers or components having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope or spirit of the present invention.

Industrial Applicability

The present invention may find particular application in antenna systems, such as those used in cellular communication systems.

What is claimed is:

1. A cellular base station telecommunication system, the system developing a beam, the system comprising:

an antenna having a plurality of radiating elements;

an electromechanical phase shifter including an electrical actuator coupled to a mechanical phase shifter, said phase shifter being operatively coupled to said plurality of radiating elements;

a controller remotely located from said antenna and operatively coupled to said phase shifter; and

a system component selected from the group consisting of a beam elevation indicator, beam position sensing circuit, and user interface.

2. The system of claim 1 wherein said controller is adapted to adjust a beam direction.

3. The system of claim 1 wherein said controller is adapted to adjust a beam downtilt.

4. The system of claim 1 wherein said controller is adapted to adjust a phasing of signals supplied to at least some of the radiating elements in response to traffic demands.

5. The system of claim 1 wherein said electromechanical phase shifter has first and second components, at least one of said components being movable with respect to the other, wherein said controller varies a phasing of signals supplied to the radiating elements by causing a relative displacement between said first component and said second component.

6. The system of claim 5 wherein said relative displacement is effected by drive devices selected from the group consisting of: a screw drive, rack-and-pinion drive, gear drive, drive mechanism having plastic components to reduce intermodulation distortion, drive mechanism carrying signals to said electromechanical phase shifter, and a pulse-driven motor.

7. The system of claim 1 wherein said controller is coupled to said electromechanical phase shifter by,a telephone link.

8. The system of claim 1 wherein said controller is coupled to said electromechanical phase shifter by a wireless link.

9. The system of claim 8 wherein said wireless link is a radio link.

10. The system of claim 1 further including a phase shifter lock.

11. The system of claim 1 wherein said controller is adapted to adjust a phasing of signals supplied to at least some of the radiating elements so as to cause an increase in a downtilt angle of the beam or a decrease in a downtilt angle of the beam.

12. The system of claim 1 wherein said controller is adapted to produce selected different phasing of signals supplied to at least some of the radiating elements.

13. The system of claim 1 wherein said controller is adapted to change a phasing of signals supplied to at least some of the radiating elements by predetermined amounts.

14. The system of claim 1 wherein said controller is adapted to measure a phase value of signals supplied to at least some of the radiating elements.

15. The system of claim 1 wherein said controller is adapted to identify a status of said antenna.

16. The system of claim 1 further including a motor operatively coupled to said electromechanical phase shifter, said electromechanical phase shifter having first and second components, at least one of said components being movable with respect to the other, and wherein said controller supplies drive signals to said motor to cause at least one of said first and second components to move relative to the other.

17. The system of claim 16 wherein a portion of the beam elevation indicator comprises a sensor operatively coupled to the motor.

18. The system of claim 1 wherein a portion of the beam elevation indicator comprises a sensor operatively coupled to the phase shifter.

19. The system of claim 16 wherein a portion of the beam elevation indicator detects movement of a component of the motor.

20. The system of claim 16 wherein the beam elevation indicator detects rotational movement of the motor.

21. The system of claim 16 wherein the controller receives a signal from the beam elevation indicator, said signal corresponding to rotational movement of the motor.

22. The system of claim 16 wherein the beam elevation indicator detects movement of at least one of the first and second components of the phase shifter.

23. The system of claim 16 wherein the controller stores in memory a value corresponding to a number of movements of the motor.

24. The system of claim 16 wherein the controller supplies drive pulses to the motor and stores in memory an indication of a number of drive pulses provided to the motor.

25. The system of claim 16 further including a limit indicator operatively coupled to the electromechanical phase shifter and configured to provide an indication to the controller when the electromechanical phase shifter is in a displacement limit position.

26. The system of claim 1 further including a left limit indicator and a right limit indicator operatively coupled to the electromechanical phase shifter and configured to provide an indication to the controller when the electromechanical phase shifter is in a left most or right most position, respectively.

27. The system of claim 25 wherein at least one of the first and second components of the phase shifter is physically displaced from the other by a maximum amount when the phase shifter is in the displacement limit position.

28. The system of claim 25 wherein at least one of the first and second components of the phase shifter is physically displaced from the other by a minimum amount when the phase shifter is in the displacement limit position.

29. The system of claim 25 wherein the controller resets the electromechanical phase shifter to a known position by activating the motor to place the electromechanical phase shifter in the displacement limit position.

30. The system of claim 25 wherein the controller determines a beam angle of the antenna by moving at least one of the first and second components of the phase shifter from a current position to the displacement limit position and counting a number of pulses supplied to the motor to effect such movement, said number of pulses being stored in a memory to represent a current antenna beam angle value.

31. The system of claim 30 wherein the controller updates the current antenna beam angle value after the phase shifter has been moved to a new position, said current antenna beam angle value being modified by a number of pulses provided to the motor to move the phase shifter to the new position.

32. The system of claim 16 further including a table stored in a memory of the controller containing data correlating a desired antenna beam angle with a number of pulses to be provided to the motor.

33. The system of claim 1 wherein the controller stores in memory an indication of a beam angle of the antenna.

34. The system of claim 1 wherein the controller stores in memory an updated indication of a beam angle of the antenna corresponding to a change in downtilt.

35. The system of claim 16 further including a sensor coupled to the motor to provide an indication to the controller of a number of motor movements, said number of movements corresponding to relative movement between the first and second components of the phase shifter.

36. The system of claim 35 wherein the sensor is coupled to at least one of the first and second components of the phase shifter to provide an indication to the controller, said indication corresponding to relative movement between the first and second components of the phase shifter.

37. The system of claim 1 wherein the beam elevation indicator includes a Hall-effect device.

38. The system of claim 16 wherein the beam elevation indicator includes a magnetic sensor that provides a signal to the controller corresponding to relative movement between the first and second components of the phase shifter.

39. The system of claim 1 further including a user interface operatively coupled to the controller.

40. The system of claim 39 wherein the user interface is wirelessly coupled to the controller.

41. The system of claim 39 wherein the user interface is coupled to the controller by a telephonic link.

42. The system of claim 39 wherein the user interface permits a plurality of actions to be taken, said actions selected from the group of actions consisting of: a) selecting one of a plurality of antennas, b) setting an antenna beam angle, c) nudging an antenna beam angle, d) resetting an antenna beam angle, e) measuring an antenna beam angle, f) enabling an antenna, g) disabling an antenna, h) locking controls of the user interface, and i) unlocking controls of the user interface.

43. The system of claim 39 wherein the user interface provides a plurality of indications, said indications selected from the group of indications consisting of: a) the antenna beam angle could not be set, b) the antenna beam angle could not be measured, c) the antenna could not be enabled, d) the antenna could not be locked, e) the controller was not able to communication with the antenna, f) motor failure, g) an antenna error has occurred, h) the antenna could not be nudged, and i) the antenna is functioning normally.

44. The system of claim 39 wherein data corresponding to antenna beam angle parameters is stored in a file accessible by the controller.

45. The system of claim 16 wherein said motor is a stepper motor.

46. The system of claim 16 wherein said controller supplies a predetermined number of drive pulses to said motor.

47. The system of claim 16 wherein said motor is located on said antenna.

48. The system of claim 16 wherein said motor is mechanically coupled to said phase shifter and drives said phase shifter.

49. A cellular base station telecommunication system, the system developing a beam, the system comprising:

an antenna having a plurality of radiating elements;

an electromechanical phase shifter including an electrical actuator coupled to a mechanical phase shifter, said phase shifter being operatively coupled to said plurality of radiating elements;

a controller remotely located from said antenna and operatively coupled to said phase shifter; and

sensing circuitry adapted to determine a position of the beam.

50. A cellular base station telecommunication system, the system developing a beam, the system comprising:

an antenna having a plurality of radiating elements;

an electromechanical phase shifter including an electrical actuator coupled to a mechanical phase shifter, said phase shifter being operatively coupled to said plurality of radiating elements;

a controller remotely located from said antenna and operatively coupled to said phase shifter; and

a user interface operatively coupled to the controller.

51. The system of claim 50 wherein the user interface is wirelessly coupled to the controller.

52. The system of claim 50 wherein the user interface permits a plurality of actions to be taken, said actions selected from the group of actions consisting of: a) selecting one of a plurality of antennas, b) setting an antenna beam angle, c) nudging an antenna beam angle, d) resetting an antenna beam angle, e) measuring an antenna beam angle, f) enabling an antenna, g) disabling an antenna, h) locking controls of the user interface, and i) unlocking controls of the user interface.

53. The system of claim 50 wherein the user interface provides a plurality of indications, said indications selected from the group of indications consisting of: a) the antenna beam angle could not be set, b) the antenna beam angle could not be measured, c) the antenna could not be enabled, d) the antenna could not be locked, e) the controller was not able to communication with the antenna, f) motor failure, g) an antenna error has occurred, h) the antenna could not be nudged, and i) the antenna is functioning normally.

54. A cellular base station telecommunication system, the system developing a beam having a fixed elevation, the system comprising:

an antenna having a plurality of radiating elements;

an electromechanical phase shifter operatively coupled to said plurality of radiating elements and to an electrical actuator; and

a controller located remotely from said antenna and operatively coupled to said electrical actuator and to a beam elevation indicator, a user interface coupled to said controller and configured to facilitate adjustment of the beam from a first fixed elevation to a second fixed elevation.

55. The system defined by claim 54 wherein said electrical actuator includes a stepper motor, said electromechanical phase shifter having first and second components, at least one of said components being movable with respect to the other, wherein said controller supplies drive signals to said motor to cause at least one of said first and second components to move.

56. The system of claim 55 wherein the controller stores in memory a value corresponding to a number of movements of the motor.

57. The system of claim 55 wherein the controller supplies drive pulses to the motor and stores in memory an indication of a number of drive pulses provided to the motor.

58. The system of claim 54 further including a limit indicator operatively coupled to the electromechanical phase shifter and configured to provide an indication to the controller when the electromechanical phase shifter is in a maximum displacement limit position.

59. The system of claim 54 further including a left limit indicator and a right limit indicator operatively coupled to the electromechanical phase shifter and configured to provide an indication to the controller when the electromechanical phase shifter is in a left-most or right-most position, respectively.

60. The system of claim 55 wherein at least one of the first and second components of the phase shifter is physically displaced from the other by a maximum amount when the phase shifter is in the displacement limit position.

61. The system of claim 55 wherein at least one of the first and second components of the phase shifter is physically displaced from the other by a minimum amount when the phase shifter is in the displacement limit position.

62. The system of claim 55 wherein the controller resets the electromechanical phase shifter to a known position by activating the motor so as to place the electromechanical phase shifter in the displacement limit position.

63. The system of claim 55 wherein the controller determines a beam angle of the antenna by moving at least one of the first and second components of the phase shifter from a current position to the displacement limit position and by counting a number of pulses supplied to the motor to effect such movement, said number of pulses being stored in a memory to represent a current antenna beam angle value.

64. The system of claim 63 wherein the controller updates the current antenna beam angle value after the phase shifter has been moved to new position, said current antenna beam angle value being modified by a number of pulses provided to the motor to move the phase shifter to the new position.

65. The system of claim 55 further including a table stored in a memory of the controller containing data correlating a desired antenna beam angle with a number of pulses to be provided to the motor.

66. The system of claim 54 wherein the controller stores in memory an indication of a beam angle of the antenna.

67. The system of claim 55 wherein said motor is located on said antenna.

68. The system of claim 55 wherein said motor is mechanically coupled to said phase shifter and drives said phase shifter.

69. A method of adjusting a beam in a cellular base station telecommunication system, the system having an antenna with a plurality of radiating elements, the method comprising the steps of:

providing an electromechanical phase shifter;

coupling said electromechanical phase shifter to said plurality of radiating elements;

controlling the electromechanical phase shifter from a location remote from the antenna to adjust a phasing of signals supplied to at least some of the radiating elements; and

sensing a position of the beam by the controller.

70. The method of claim 69 wherein said electromechanical phase shifter is adapted to adjust a direction of said beam.

71. The method of claim 69 wherein said electromechanical phase shifter is adapted to adjust a downtilt of said beam.

72. The method of claim 69 wherein said electromechanical phase shifter is adapted to adjust a phasing of signals supplied to at least selected radiating elements in response to traffic demands.

73. The method of claim 69 further including the steps of providing said electromechanical phase shifter with first and second components, at least one of said components being movable with respect to the other, and varying a phasing of signals supplied to at least some of the radiating elements by causing a relative displacement between said first component and said second component.

74. The method of claim 73 further including the steps of:

providing a pulse-driven motor;

causing the motor to displace at least one of the first and second components to a displacement limit position corresponding to a predetermined signal phasing; and

providing a predetermined number of pulses to the motor to cause the motor to displace at least one of the first and second components away from said displacement limit position by a predetermined amount so as to achieve a predetermined signal phasing.

75. The method of claim 69 further including the step of adjusting said electromechanical phase shifter to produce an increase in a beam angle or a decrease in a beam angle, said adjusting performed by said controller.

76. The method of claim 69 including the step of adjusting said electromechanical phase shifter to produce selected different phasing of signals supplied to at least some of the radiating elements, said adjusting performed by said controller.

77. The method of claim 69 including the step of adjusting a phasing of signals supplied to at least selected radiating elements by predetermined amounts, said adjusting performed by said controller.

78. The method of claim 74 further including the step of the controller storing in memory a value of a number of movements of the motor.

79. The method of claim 74 further including the step of the controller supplying drive pulses to the motor and storing in memory an indication of a number of drive pulses provided to the motor.

80. The method of claim 74 further including the step of operatively coupling a limit indicator to the electromechanical phase shifter, the limit indicator configured to provide an indication to the controller when the electromechanical phase shifter is in a displacement limit position.

81. The method of claim 80 further including the step of activating the motor to place the electromechanical phase shifter in the displacement limit position to place the electromechanical phase shifter in a known position.

82. The method of claim 80 further including the step of moving at least one of the first and second components of the phase shifter from a current position to the displacement limit position and counting a number of pulses supplied to the motor to effect such movement, said number of pulses being stored in a memory to represent a current beam angle.

83. The method of claim 82 further including the step of updating the current antenna beam angle number after the phase shifter has been moved to new position, said current antenna beam angle value being modified by a number of pulses provided to the motor to move the phase shifter to the new position.

84. The method of claim 74 further including the step of providing a table in a memory of the controller, the table containing data correlating a desired antenna beam angle value with a number of pulses to be provided to the motor.

85. The method of claim 69 further including the step storing in memory of the controller an indication of a beam angle of the antenna.

86. The method of claim 69 further including the step storing in memory of the controller an updated indication of a beam angle of the antenna corresponding to a change in downtilt.

87. The method of claim 74 further including the step coupling a sensor to the motor, and providing an indication to the controller corresponding to a number of motor movements, said number of movements corresponding to physical movement between the first and second components of the phase shifter.

88. The method of claim 73 further including the step of coupling a sensor to at least one of the first and second components of the phase shifter to provide an indication to the controller corresponding to relative movement between the first and second components of the phase shifter.

89. The method of claim 69 further including the step of providing a user interface, the user interface permitting selection of a plurality of actions to be taken, said actions selected from the group of actions consisting of; a) selecting one of a plurality of antennas, b) setting an antenna beam angle, c) nudging an antenna beam angle, d) resetting an antenna beam angle, e) measuring an antenna beam angle, f) enabling an antenna, g) disabling an antenna, h) locking controls of the user interface, and i) unlocking controls of the user interface.

90. The method of claim 69 further including the step of providing a user interface, the user interface providing a plurality of indications, said indications selected from the group of indications consisting of: a) the antenna beam angle could not be set, b) the antenna beam angle could not be measured, c) the antenna could not be enabled, d) the antenna could not be locked, e) the controller was not able to communication with the antenna, f) motor failure, g) an antenna error has occurred, h) the antenna could not be nudged, and i) the antenna is functioning normally.

* * * * *

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(12) **United States Patent**
Heinz et al.

(10) **Patent No.: US 6,600,457 B2**
(45) **Date of Patent: Jul. 29, 2003**

(54) **ANTENNA CONTROL SYSTEM**

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(73) Assignee: **Andrew Corporation**, Orlando Park, IL (US)

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(58) **Field of Search** 455/33.4, 33.1, 455/33.3, 54.1, 62; 343/890, 853; 333/246

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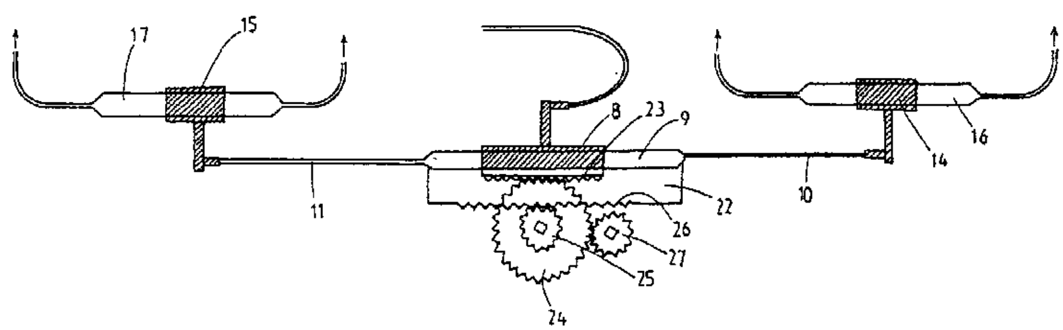
(57) **ABSTRACT**

An antenna control system enabling the remote variation of antenna beam tilt. A drive means continuously adjusts phase shifters of a feed distribution network to radiating elements to continuously vary antenna beam tilt. A controller enables the beam tilt of a number of antenna at a site to be remotely varied.

69 Claims, 8 Drawing Sheets



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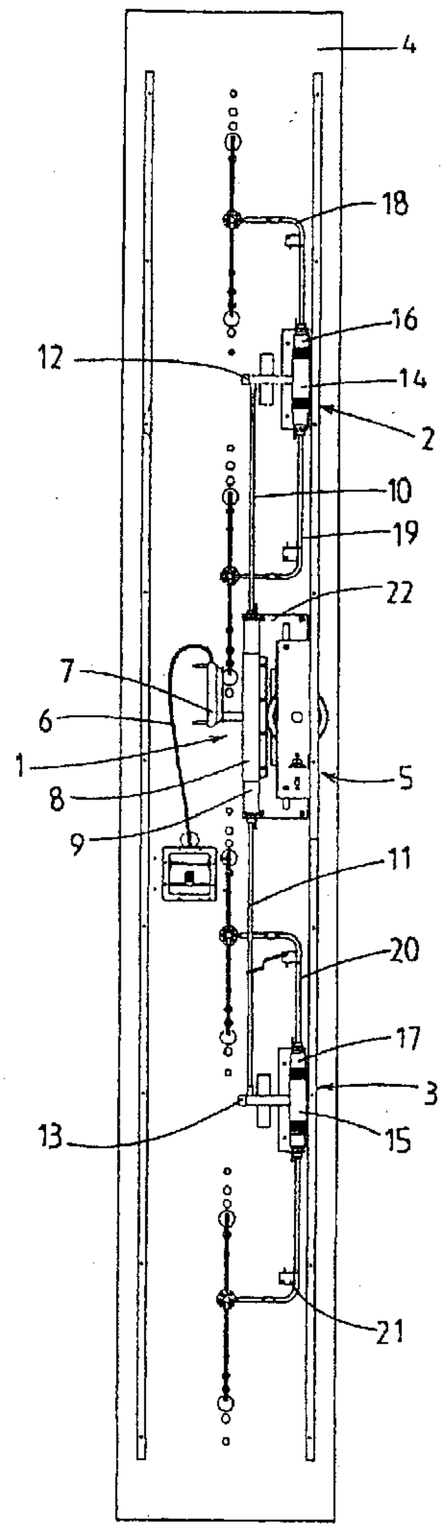

FIG.1

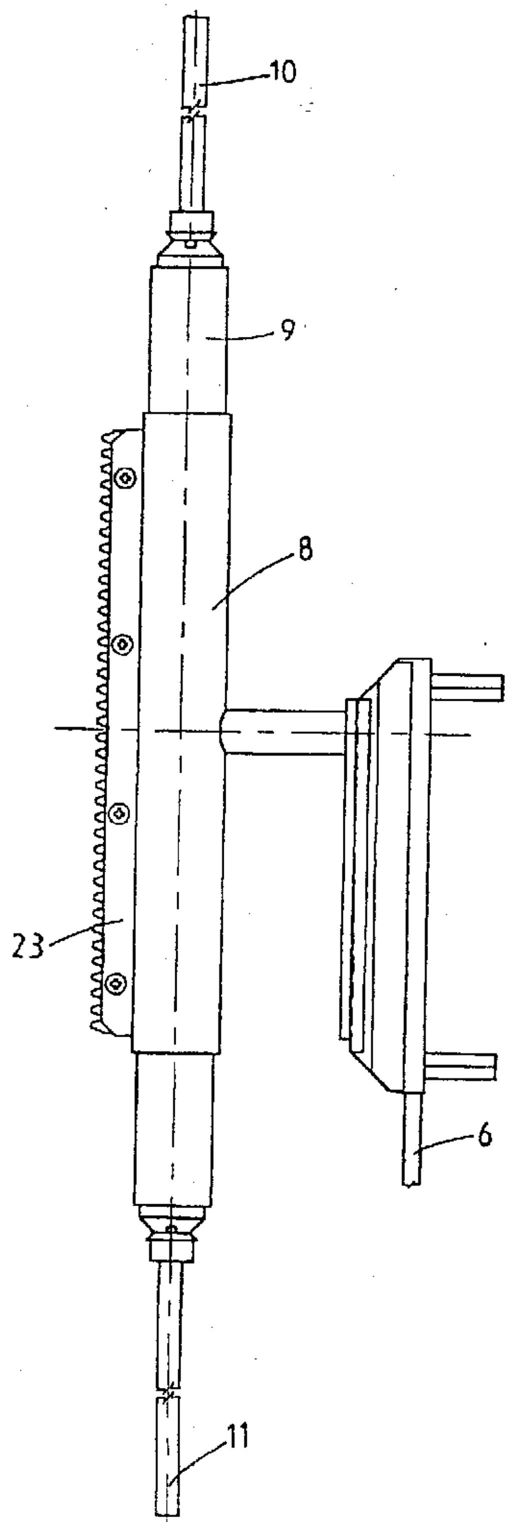

FIG. 2

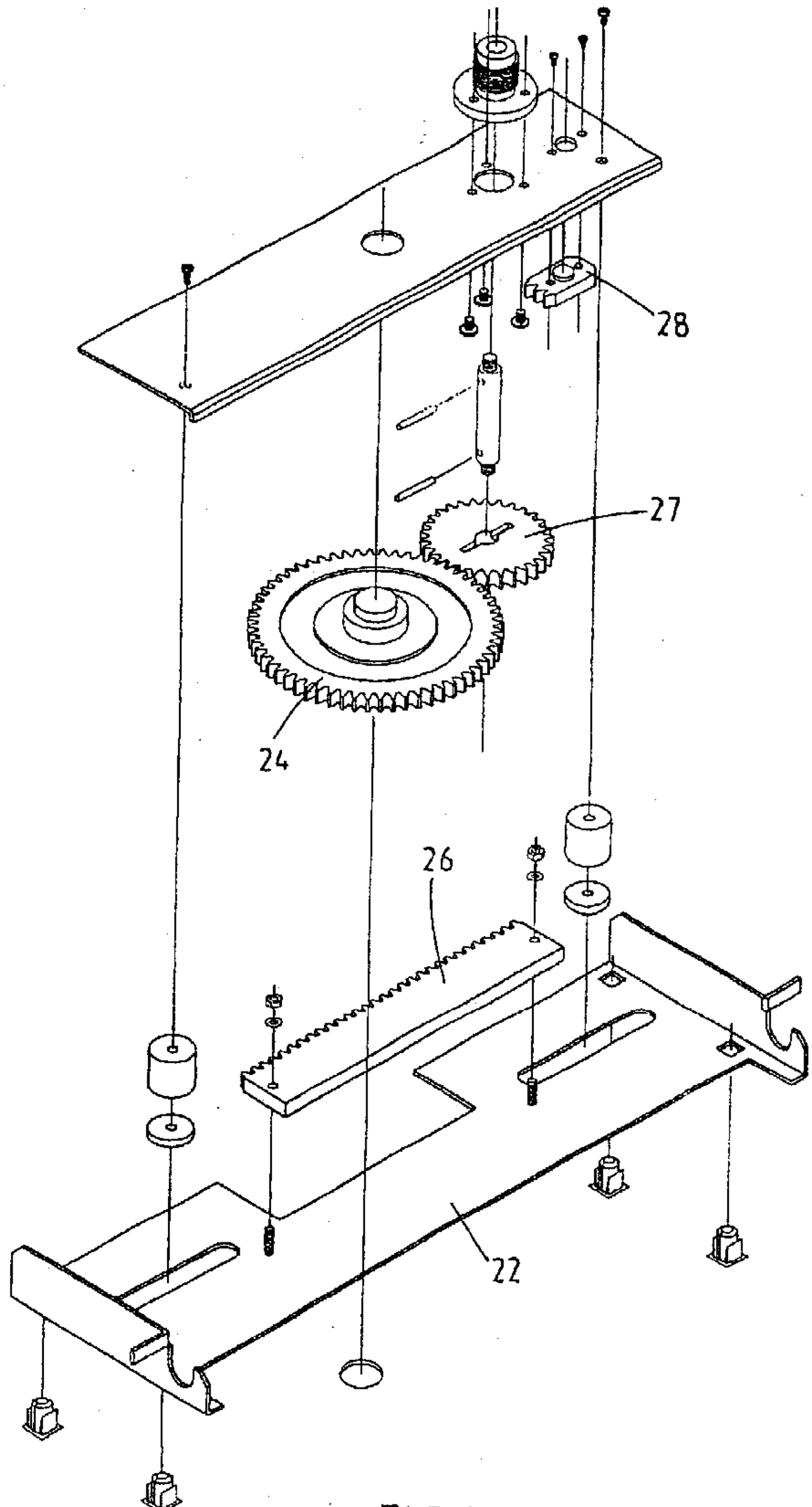

FIG. 3

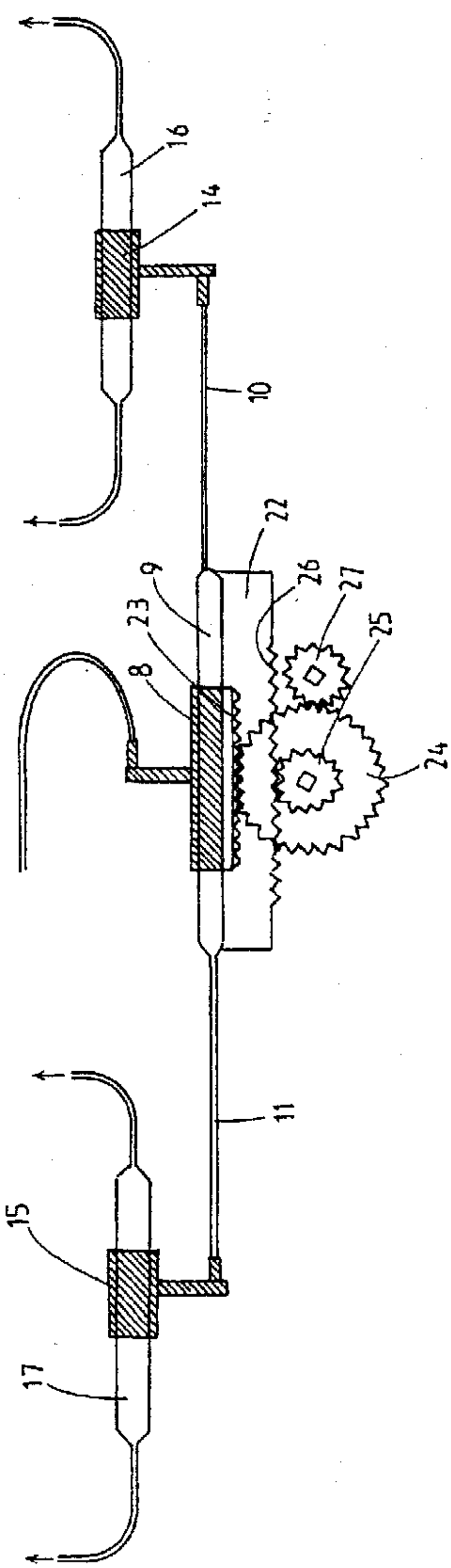

FIG.4

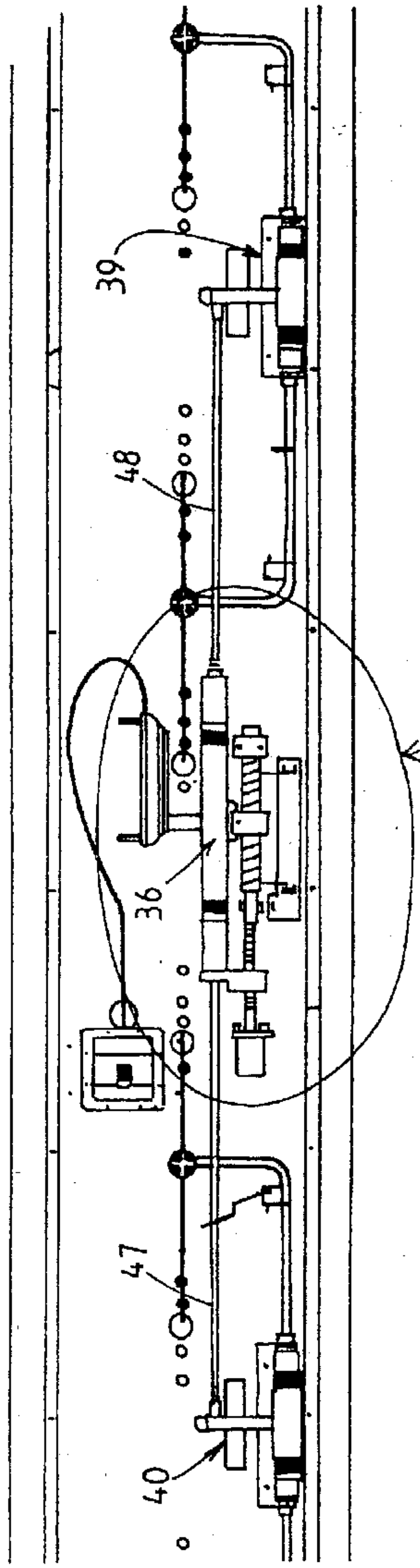

FIG. 5

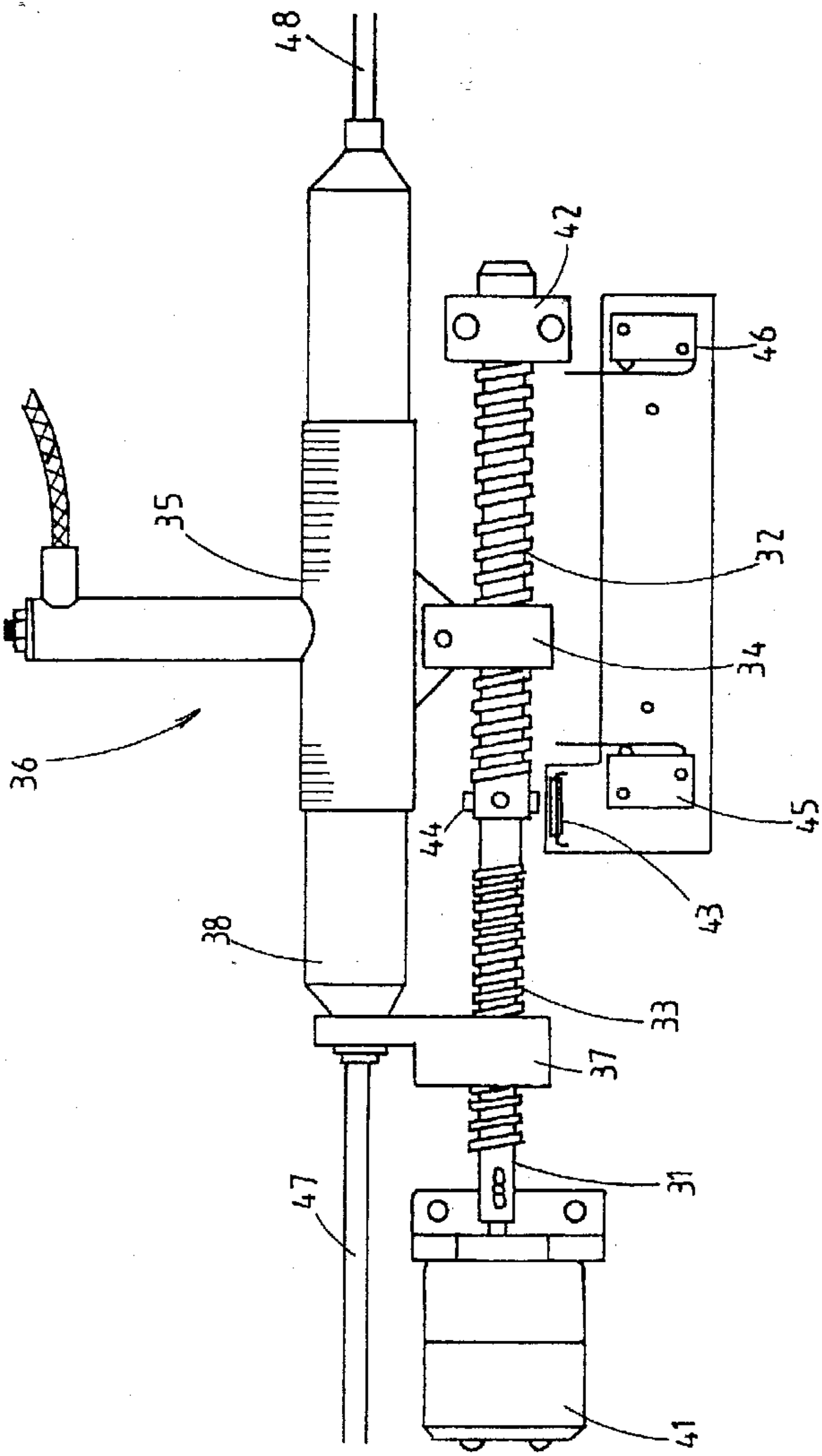

FIG. 6

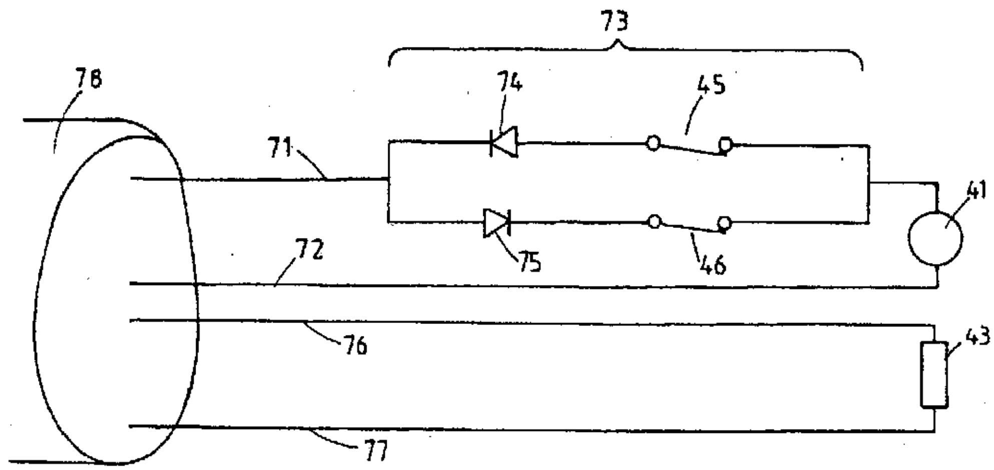

FIG. 7

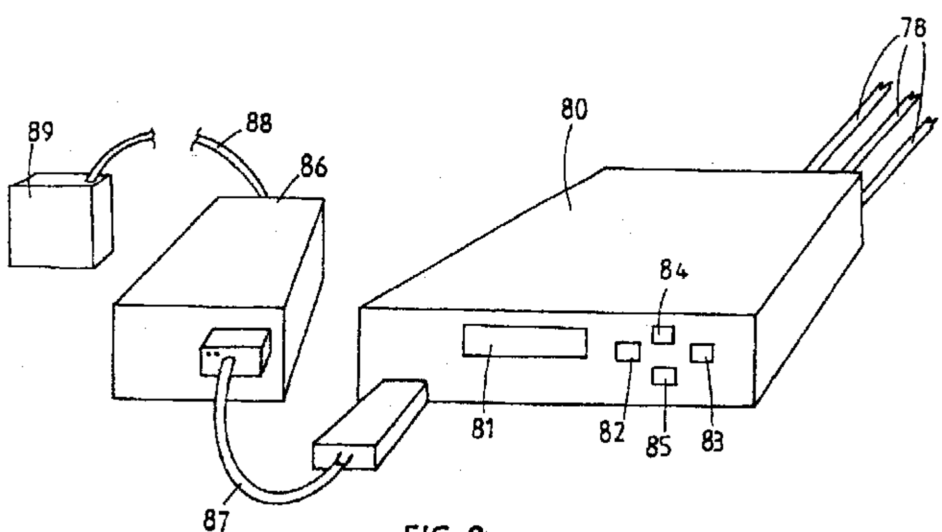

FIG. 8

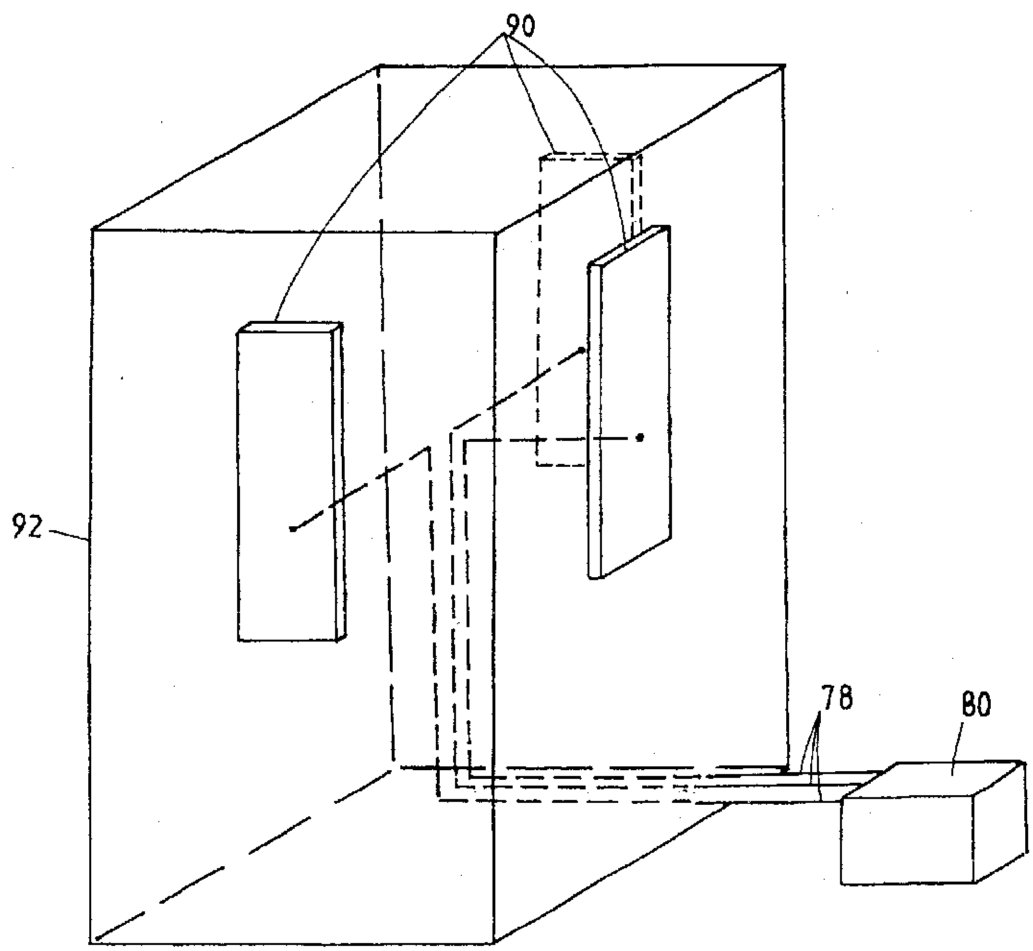

FIG. 9

ANTENNA CONTROL SYSTEM

This is a continuation of application Ser. No. 09/713,614, filed Nov. 15, 2000, entitled Antenna Control System, now U.S. Pat. No. 6,346,924, which is a continuation of application Ser. No. 08/817,445, filed Apr. 30, 1997, entitled Antenna Control System, now U.S. Pat. No. 6,198,458 B1 which is a 371 of PCT/NZ95/00106, filed Oct. 10, 1995.

THE TECHNICAL FIELD

The present invention relates to an antenna control system for varying the beam tilt of one or more antenna. More particularly, although not exclusively, the present invention relates to a drive system for use in an antenna which incorporates one or more phase shifter.

BACKGROUND OF THE INVENTION

In order to produce downtilt in the beam produced by an antenna array (for example a panel antenna) it is possible to either mechanically tilt the panel antenna or electrically steer the beam radiated from the panel antenna according to techniques known in the art.

Panel antennas, such as those to which the present application is concerned, are often located on the sides of buildings or similar structures. Mechanical tilting of the antenna away from the side of the building increases the susceptibility of the installation to wind induced vibration and can impact on the visual environment in situations where significant amounts of downtilt are required.

In order to avoid the above difficulties, electrical beam steering can be effected by introducing phase delays into the signal input into radiating elements or groups of radiating elements in an antenna array.

Such techniques are described in New Zealand Patent Specification No. 235010.

Various phase delay techniques are known, including inserting variable length delay lines into the network feeding to the radiating element or elements, or using PIN diodes to vary the phase of a signal transmitted through the feeder network.

A further means for varying the phase of two signals is described in PCT/NZ94/00107 whose disclosure is incorporated herein by reference. This specification describes a mechanically operated variable differential phase shifter incorporating one input and two outputs.

For the present purposes it is sufficient to note that phase shifters such as those described in PCT/NZ94/00107 are adjusted mechanically by sliding an external sleeve along the body of the phase shifter which alters the relative phase of the signals at the phase shifter outputs.

A typical panel antenna will incorporate one or more phase shifters and the present particular embodiment includes three phase shifters. A signal is input to the primary phase shifter which splits the signal into two signals having a desired phase relationship. Each phase shifted signal is then input into a secondary phase shifter whose outputs feeds at least one radiating element. In this manner a progressive phase shift can be achieved across the entire radiating element array, thus providing a means for electrically adjusting the downtilt of the radiated beam. Other phase distributions are possible depending on the application and shape of the radiated beam.

While the steering action is discussed in the context of downtilt of the radiated beam, it is to be understood that the present detailed description is not limited to such a direction. Beam tilt may be produced in any desired direction.

Another particular feature of the variable differential phase shifters is that they provide a continuous phase adjustment, in contrast with the more conventional stepped phase adjustments normally found in PIN diode or stepped length delay line phase shifters.

In a panel antenna of the type presently under consideration, it is desirable to adjust the entire phase shifter array simultaneously so that a desired degree of beam tilt may be set by the adjustment of a single mechanical setting means. The mechanical drive which performs such an adjustment must result in reproducible downtilt angles and be able to be adapted to provide for a number of different phase shifter array configurations.

It is also desirable that the beam tilt of an antenna may be varied remotely to avoid the need for personnel to climb a structure to adjust antenna beam tilt.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a mechanical drive system for use in adjusting mechanical phase shifters which mitigates the abovementioned difficulties, provides a solution to the design requirements of the antennas or antenna arrays described above, or at least provides the public with a useful choice.

Accordingly, there is provided a mechanical adjustment means for adjusting the relative phase shifts produced by a plurality of phase shifters connected to an array of radiating elements, said mechanical adjustment means including:

first means for moving a first portion of a first phase shifter relative to a second portion of said first phase shifter to vary the phase difference between output signals from the first phase shifter; and

second means for moving a first portion of a second phase shifter relative to a second portion of said second phase shifter to vary the phase difference between output signals from the second phase shifter, wherein the second phase shifter is fed from an output of the first phase shifter and the degree of movement of the second means is dependent upon the degree of movement of the first means.

Preferably, movement of the second means results in simultaneous movement of a first portion of a third phase shifter with respect to a second portion of the third phase shifter wherein the third phase shifter is fed from an output of the first phase shifter.

Preferably the outputs of the second and third phase shifters are connected to radiating elements so as to produce a beam which tilts as the first and second means adjusts the phase shifters.

Preferably the movement of the first portion of the first phase shifter a first distance relative to the second portion of the first phase shifter results in relative movement between first portions of the second and third phase shifters relative to second portions of the second and third phase shifters of about twice the first distance.

According to a first preferred embodiment the first means includes a gear wheel which drives a rack connected to a first portion of the first phase shifter, arranged so that rotation of the first gear wheel causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter. Preferably, the second portion of the first phase shifter is mounted to a carriage and the outputs of the first phase shifter are connected to inputs of the second and third phase shifters by push rods so that movement of the second portion of the first phase shifter moves the first portions of the second and third phase shifters with respect to the second portions of the second and third phase shifters.

Preferably a second gear is provided co-axial with and connected to a shaft driving the first gear which drives a rack connected to the second part of the first phase shifter so that rotation of the second gear causes movement of the first portion of the second and third phase shifters relative to the second portions of the second and third phase shifters.

Preferably the ratio between the first and second gear wheels is about 3:1.

According to a second embodiment of the present invention the adjustment means includes a shaft and said first means includes a first threaded portion provided on said shaft and a first cooperating threaded member connected to the first portion of the first phase shifter. The second means includes a second threaded portion provided on said shaft and a second cooperating threaded member connected to the first portion of the second phase shifter. The arrangement is such that rotation of the shaft causes the first portion of the first phase shifter to move relative to the second portion of the first phase shifter at a rate of about twice that of the movement of the first portion of the second phase shifter relative to the second portion of the second phase shifter.

Preferably the second threaded member is connected to the second portion of the first phase shifter and moves the first portion of the second phase shifter via a push rod. This push rod is preferably a coaxial line connecting an output from the first phase shifter to the input to the second phase shifter.

Preferably there is further provided a third phase shifter fed from a second output of the first phase shifter via a push rod which moves a first portion of the third phase shifter in unison with the first portion of the second phase shifter.

According to a further aspect of the invention there is provided an antenna system comprising one or more antenna including electromechanical means for varying the downtilt of the antenna and a controller, external to the antenna, for supplying drive signals to the electromechanical means for adjusting downtilt.

Preferably the system includes a plurality of antennas and the controller may adjust the downtilt for the plurality of antennas and store the degree of downtilt of each antenna in memory.

Preferably the controller may be controlled remotely from a control centre so that a plurality of such systems may be remotely controlled as part of a control strategy for a number of cellular base stations.

Preferably the electromechanical means varies the electrical downtilt of each antenna and means are included for monitoring the electromechanical means and providing signals representative of the position of the electromechanical means to the controller.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1: shows a panel antenna incorporating a phase shifter drive mechanism according to a first embodiment of the invention.

FIG. 2: illustrates a primary phase shifter incorporating a gear rack.

FIG. 3: illustrates an exploded view of the adjustment assembly incorporated into the carriage.

FIG. 4: shows diagrammatically the operation of the drive mechanism according to the first embodiment.

FIG. 5: shows a panel antenna incorporating a phase shifter drive mechanism according to a second embodiment of the invention.

FIG. 6: shows the phase shifter drive mechanism of FIG. 5 in detail.

FIG. 7: shows the electrical connection of the motor, switches and reed switch of the drive mechanism shown in FIG. 6.

FIG. 8: shows a controller for controlling the drive mechanism shown in FIGS. 6 and 7.

FIG. 9: shows an antenna system according to one aspect of the present invention having a plurality of antennas controlled by a controller.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to FIG. 1 there is shown the back side of a panel antenna 4 having a first phase shifter 1, a second phase shifter 2, a third phase shifter 3 and a phase shifter drive mechanism 5. Feed line 6 is connected to input 7 of phase shifter 1. A first portion 8 of phase shifter 1 is moveable relative to a second portion 9 of phase shifter 1.

Output signals from phase shifter 1 are supplied via lines 10 and 11 to inputs 12 and 13 of phase shifters 2 and 3 respectively. Feed lines 10 and 11 comprise coaxial push rods which serve the functions both of feeding signals from the outputs of phase shifter 1 to phase shifters 2 and 3 and moving first portions 14 and 15 of phase shifters 2 and 3 relative to second portion 16 and 17 of phase shifters 2 and 3 respectively.

Signals output from phase shifters 2 and 3 are supplied via coaxial lines 18, 19, 20 and 21 to be fed to respective radiating elements (not shown).

In use first portion 8 of phase shifter 1 may be moved relative to second portion 9 of phase shifter 1 to change the relative phase of signals supplied via lines 10 and 11 to phase shifters 2 and 3 respectively. First portions 14 and 15 of phase shifters 2 and 3 may be moved relative to second portions 16 and 17 of phase shifters 2 and 3 to vary the phase of signals supplied by lines 18, 19, 20 and 21 to respective radiating elements.

When phase shifters 1, 2 and 3 are adjusted in the correct respective portions the beam emitted by the antenna can be tilted as required. It will be appreciated that where a less defined beam is required fewer phase shifters may be employed.

To achieve even continuous beam tilting for the embodiment shown in FIG. 1 the first portions 14 and 15 of phase shifters 2 and 3 should move relative to the second portion 16 and 17 of phase shifters 2 and 3 at the same rate. The first portion 8 of phase shifter 1 must however move relative to the second portion 9 of phase shifter 1 at twice this rate. In the arrangement shown second portion 9 of phase shifter 1 is connected to carriage 22. Movement of carriage 22 results in movement of first portions 14 and 15 of phase shifters 2 and 3 via push rods 10 and 11.

Referring now to FIG. 4, operation of the phase shifter drive mechanism will be explained. Second portion 9 of phase shifter 1 is mounted to a carriage 22 which can move left and right. If carriage 22 is moved to the left first portions 14 and 15 of phase shifters 2 and 3 will be moved to the left via push rods 10 and 11. First portion 8 of phase shifter 1 may be moved relative to second portion 9 of phase shifter 1 to vary the phase of signal supplied to phase shifters 2 and 3.

According to this first embodiment a rack 23 is secured to first portion 8 of phase shifter 1. Upon rotation of gear wheel 24 first portion 8 of phase shifter 1 may be moved to the left or the right. A smaller gear wheel 25 is secured to and rotates with gear wheel 24. This gear wheel engages with a rack 26 provided on carriage 22. A further gear wheel 27 is provided which may be driven to rotate gear wheels 24 and 25 simultaneously.

Gear wheel 24 has 90 teeth whereas gear wheel 25 has 30 teeth. It will therefore be appreciated that rotation of gear wheel 24 results in first portion 8 of phase shifter 1 being moved three times as far as carriage 22 (and hence first portions 14 and 15 of phase shifters 2 and 3). However, as carriage 22 is moving in the same direction as the first portion 8 of phase shifter 1 it will be appreciated that the relative movement between first portion 8 and second portion 9 of phase shifter 1 is twice that of the relative movement between the first and second portions of phase shifters 2 and 3. Accordingly, this arrangement results in the relative phase shift produced by phase shifter 1 being twice that produced by phase shifters 2 and 3 (as required to produce even beam tilting in a branched feed arrangement).

The particular arrangement is shown in more detail in FIGS. 2 to 4. It will be appreciated that gear wheel 27 may be driven by any appropriate manual or driven means. Gear wheel 27 may be adjusted by a knob, lever, stepper motor or other driven actuator. A keeper 28 may be secured in place to prevent movement once the desired settings of the phase shifters have been achieved.

Referring now to FIGS. 5 and 6, a second embodiment will be described. As seen in FIG. 5, the arrangement is substantially the same as that shown in the first embodiment except for the drive mechanism 30 employed, which is shown in FIG. 6.

In this embodiment the drive mechanism includes a shaft 31 having a first threaded portion 32 and a second threaded portion 33 provided thereon. A first threaded member 34 is connected to a first portion 35 of primary phase shifter 36. A second threaded member 37 is connected to the second portion 38 of primary phase shifter 36.

First threaded portion 32 is of three times the pitch of second threaded portion 33 (e.g. the pitch of the first threaded portion 32 is 6 mm whereas the pitch of the second threaded portion is 2 mm). In this way, first portion 35 is driven in the direction of movement at three times that of second portion 38. In this way the phase shift produced by primary phase shifter 36 is twice that of second and third phase shifters 39 and 40.

Shaft 31 is rotated by motor 41. This may suitably be a geared down 12 volt DC motor. The other end of shaft 31 is supported by end bearing 42. A reed switch 43 is provided to detect when magnets 44 pass thereby. In this way the number of rotations of shaft 31 may be monitored. Limit switches 45 and 46 may be provided so that the motor is prevented from further driving shaft 31 in a given direction if threaded member 34 abuts a lever of limit switch 45 or 46 respectively.

Operation of the drive means according to the second embodiment will now be described by way of example. Motor 41 may rotate shaft 31 in an anticlockwise direction, viewed from right to left along shaft 31. Threaded member 37 is driven by second threaded portion 33 to move push rods 47 and 48 to the left, and thus to adjust phase shifters 39 and 40.

Threaded member 34 is driven to the left at three times the rate of threaded member 37. First portion 35 thus moves to the left at three times the rate of second portion 38. First portion 35 therefore moves relative to second portion 38 at twice the speed the first portions of phase shifters 39 and 40

move relative to their respective second portions. In this way, delays are introduced in the paths to respective radiating elements so as to produce an evenly tilting beam.

The conductivity of reed switch 43 is monitored so that the number of rotations, or part rotations, of shaft 31 may be monitored. If the motor continues driving shaft 31 until threaded member 34 abuts the lever of limit switch 45 then logic circuitry will only permit motor 41 to drive in the opposite direction. Likewise if threaded member 34 abuts the lever of limit switch 46 the motor 41 will only be permitted to drive in the opposite direction.

It will be appreciated that the techniques of both embodiments could be employed in antenna arrays using a larger number of phase shifters. In such applications the relative movement of the first portion of each phase shifter relative to the second portion of each phase shifter would decreased by a factor of 2 for each successive phase shifter along each branch. The ratios used may be varied if the radiation pattern of the antenna needs to be altered to account for the directivity of the individual radiating elements and the effect of the back panel as the amount of downtilt is varied.

Components of the drive mechanism 30 are preferably formed of plastics, where possible, to reduce intermodulation. Threaded members 34 and 37 preferably include plastic links to phase shifter 36 to reduce intermodulation.

It will be appreciated that a number of mechanical drive arrangements may be used to achieve adjustment of the phase shifters in the desired ratio. It is also to be appreciated that sophisticated control electronics may be employed, although the simplicity of construction of the present invention is seen as an advantage.

FIG. 7 shows how motor 41, reed switch 43 and switches 45 and 46 are connected to lines 71, 72, 76 and 77 from an external controller. Lines 71, 72, 76 and 77 are sheathed by conduit 78. Lines 71 and 72 supply current to drive motor 41. Section 73 ensures that if threaded member 34 is driven to either the left-hand side limit or the right-hand side limit it can only be driven in the opposite direction. In the position shown in FIG. 7, switch 45 directly connects line 71 to switch 46 via diode 74. In the position shown switch 46 connects line 71 to motor 41 via diode 75. This is the normal position of the switches when threaded member 34 is not at either extreme limit. When threaded member 34 is driven to the extreme left, for example, and actuates switch 45, then switch 45 open circuits the path via diode 74. Diode 74 allows current flow in the direction allowing motor 41 to drive to the left. Accordingly, when switch 45 is open, motor 41 can only drive in such a direction as to drive threaded member 34 to the right (i.e.: current in the direction allowed by diode 75).

Likewise, if threaded member 34 is driven to the extreme right, switch 46 is opened to break the path via diode 75. This prevents motor 41 driving in such a direction as to drive threaded member 34 further to the right.

Lines 76 and 77 are connected to reed switch 43 so that the opening and closing of reed switch 43 may be monitored by an external control unit. In use, the opening and closing of reed switch 43 may be monitored to determine the position of threaded member 34, and hence the corresponding degree of tilt of the antenna.

To select an initial angle of downtilt threaded member 34 may be driven to the extreme right. An external controller may provide a current in one direction to motor 41 to drive member 34 to the right. The motor will continue to be driven to the right until threaded portion 34 abuts switch 46. When switch 46 is opened diode 75 will be open circuited, which will prevent the motor being driven further to the right.

The controller will sense that threaded member **34** is at its extreme right position as it will detect that reed switch **43** is not opening and closing. After a predetermined delay the controller may then provide a current in the opposite direction via lines **71** and **72** to motor **41** to drive it to the left. As the motor is driven to the left the controller will monitor the opening and closing of reed switch **43** to determine how far threaded member **34** has moved to the left. The controller will continue to move threaded member **34** to the left until reed switch **43** has opened and closed a predetermined number of times, corresponding to a desired angle of downtilt. Alternatively, threaded member **34** may be driven to the extreme left and then back to the right.

As shown in FIG. **9**, at an antenna site a number of such panels **90** may be installed and controlled by a single controller **80** as shown in FIG. **8**. The four wires **71, 72, 76,** and **77** correspond to respective cable groups **78** to three such antenna panels. Controller **80** may be provided at the base of an antenna site to allow an operator to adjust the tilt of a plurality of antennas at ground level, rather than requiring a serviceman to climb up the antenna structure **92** and adjust each antenna manually. Alternatively, controller **80** may be a hand-held unit which can be plugged into a connector at the base of an antenna to adjust the antenna at a site.

Controller **80** may include a display **81**, an "escape" button **82**, an "enter" button **83**, an "up" button **84** and "down" button **85**. At power up display **81** may simply display a home menu such as "Deltec NZ Ltd© 1995". Upon pressing any key, a base menu may be displayed including options such as:

unlock controls
set array tilt
measure tilt
enable array
disable array
lock controls

The up/down keys may be used to move through the menu and the enter key **83** used to select an option. If "unlock controls" is selected a user will then be required to enter a three digit code. The up/down keys may be used to move through the numbers 0 to 9 and enter used to select each number. If the correct code is entered "locked released" appears. If the incorrect code is entered "controls locked" appears and a user is returned to the home menu. If "set array tilt" is selected from the base menu the following may appear:

set array tilt
array:01 X.X°

The up-down keys **84, 85** may be used to select the desired array number. The enter key accepts the selected array and the previously recorded angle of downtilt may be displayed as follows:

set array tilt
array: 01 4.6°

In this example the previously set angle of downtilt with 4.6°. Using the up/down keys **84,85** a new angle may be entered. Controller **80** may then provide a current to motor **41** via lines **71** and **72** to drive threaded portion **34** in the desired direction to alter the downtilt. The opening and closing of reed switch **43** is monitored so that threaded member **34** is moved in the desired direction for a predetermined number of pulses from reed switch **43**. The downtilt for any other array may be changed in the same manner. If the controller is locked a user may view an angle of downtilt but will not be able to alter the angle.

If the "measure array" option is selected the present angle of downtilt of the antenna may be determined. Upon selecting the "measure tilt" function from the base menu, the following display appears:

measure tilt
array: 01 X.X°

The up/down buttons may be used to select the desired array. The enter key will accept the selected array. To measure the actual angle of downtilt controller **80** drives a motor **41** of an array to drive member **34** to the right. Motor **41** is driven until threaded member **34** abuts switch **46**. The controller **80** counts the number of pulses from reed switch **43** to determine how far threaded portion **34** has traveled. At the extreme right position the controller **80** determines and displays the angle of downtilt, calculated in accordance with the number of pulses connected from reed switch **43**. The controller **80** then drives threaded member **34** back in the opposite direction for the same number of pulses from reed switch **43** so that it returns to the same position. The angle of downtilt for each antenna may be stored in memory of controller **80**. This value will be updated whenever the actual angle of downtilt is measured in this way. The "measure tilt" function may not be used if the controller is locked.

Controller **80** may include tables in memory containing the number of pulses from reed switch **43** that must be counted for threaded member **34** to achieve each desired degree of downtilt. This may be stored as a table containing the number of pulses for each required degree of downtilt, which may be in 0.1° steps. This approach ensures that any non-linearities of the antenna may be compensated for as the tables will give the actual amount of movement required to achieve a desired downtilt for a given antenna.

The "enable array" function may be used to enable each array when installed. The controller **80** will be prevented from moving any array that has not been enabled. Controller **80** will record in memory which arrays have been enabled. The "disable array" function may be used to disable arrays in a similar manner.

The "lock controls" function may be used to lock the controller once adjustment has been made. A "rack error" signal may be displayed if the array has not operated correctly. This will indicate that an operator should inspect the array.

Adjustment of the array may also be performed remotely. Controller **80** may be connected to modem **86** via serial line **87** which may connect via telephone line **88** to a central controller **89**. Alternatively, the controller **80** may be connected to a central controller **89** via a radio link etc. The functions previously discussed may be effected remotely at central controller **89**. In a computer controlled system adjustments may be made by a computer without operator intervention. In this way, the system can be integrated as part of a control strategy for a cellular base station. For example, a remote control centre **89** may adjust the downtilt of antennas at a cellular base station remotely to adjust the size of the cell in response to traffic demand. It will be appreciated that the capability to continuously and remotely control the electrical downtilt of a number of antenna of a cellular base station may be utilised in a number of control strategies.

Central controller **89** may be a computer, such as an IBM compatible PC running a windows based software program. A main screen of the program may show information regarding the antenna under control as follows:

	NAME	TYPE	CURRENT ANGLE	NEW VALUE	STATUS
GROUP 1					
antenna 1	1 south	VT01	12°	12.5°	setting
antenna 2	1 north	VT01	12°	12.5°	queued
antenna 3	1 west	VT01	12°	12.5°	queued
GROUP 2					
antenna 4	2 south	VT01	6°		pending
antenna 5	2 north	VT01	6°	.5°	nudging
antenna 6	2 west	VT01	6°		faulty

The antennas may be arranged in groups at each site. Group 1 for example contains antennas 1, 2 and 3. The following information about each antenna is given:

Name: this is the user assigned name such as 1 south, 1 north, 1 west etc.

Type: this is the antenna type which the controller communicates to the PC at start-up.

Current Angle: this is the actual degree of beam tilt of an antenna which is communicated from the controller to the PC at start-up. The controller also supplies to the PC each antenna's minimum and maximum angles of tilt.

New Value: by moving a pointer to the row of an antenna and clicking a button of a mouse the settings of an antenna may be varied. When a user clicks on the mouse the following options may be selected:

- Name—the user may change the group or antenna name.
- Adjust—a user may enter a new angle in the "new value" column to set the antenna to a new value.
- Nudge—the user may enter a relative value (i.e.: increase or decrease the tilt of an antenna by a predetermined amount).
- Measure—the controller may be instructed to measure the actual angle of tilt of an antenna or group of antennas.

If an antenna is in a "fault" condition then it may not be adjusted and if a user clicks on a mouse when that antenna is highlighted a dialogue box will appear instructing the user to clear the fault before adjusting the antenna.

Each antenna also includes a field indicating the status of the antenna as follows:

- O.K.—the antenna is functioning normally.
- Queued—an instruction to read, measure, set or nudge the antenna has been queued until the controller is ready.
- Reading—when information about an antenna is being read from the controller.
- Measuring—when the actual degree of tilt of the antenna is being measured.
- Setting—when a new tilt angle is being set.
- Nudging—when the tilt angle of the antenna is being nudged.
- Faulty—where an antenna is faulty.

When adjusting, measuring or nudging an antenna a further dialogue box may appear describing the action that has been instructed and asking a user to confirm that the action should be taken. This safeguards against undesired commands being carried out.

Information for a site may be stored in a file which can be recalled when the antenna is to be monitored or adjusted again. It will be appreciated that the software may be modified for any required control application.

Controller **80** may be a fixed controller installed in the base of an antenna site or could be a portable control unit which is plugged into connectors from control lines **78**.

Where in the foregoing description reference has been made to integers or components having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope or spirit of the present invention.

Industrial Applicability

The present invention may find particular application in antenna systems, such as those used in cellular communication systems.

What is claimed is:

1. A method for adjusting beam elevation in a cellular base station telecommunication system, the system having a plurality of separately driven arrays of radiating elements producing a like plurality of beams, the method comprising:
   - providing a respective plurality of variable phase shifters for said plurality of arrays of radiating elements; and
   - independently controlling said phase shifters from a common controller to separately adjust the elevation of each of said plurality of beams.

2. The method of claim **1** wherein said plurality of arrays comprise, respectively, part of a plurality of independent antennas.

3. The method of claim **1** wherein at least one of said phase shifters is configured to adjust a beam downtilt.

4. The method of claim **1** wherein at least one of said phase shifters is configured to adjust a phasing of signals supplied to the associated array of radiating elements in response to traffic demands.

5. The method of claim **1** wherein at least one of said phase shifters has first and second components, at least one of said components being moveable with respect to the other, and wherein causing a relative displacement between said first component and said second component varies a phasing of signals supplied to the associated array of radiating elements.

6. The method of claim **5** wherein said relative displacement is effected by drive devices selected from the group consisting of a screw drive, rack-and-pinion drive, gear drive, drive mechanism having plastic components to reduce intermodulation distortion, drive mechanism carrying signals to said electromechanical phase shifter, and a pulse-driven motor.

7. The method of claim **5** further including the steps of:
   - providing a pulse-driven motor;
   - causing the motor to displace at least one of the first and second components to a displacement limit position corresponding to a predetermined signal phasing; and
   - providing a predetermined number of pulses to the motor to cause the motor to displace at least one of the first and second components away from said displacement limit position by a predetermined amount so as to achieve a predetermined signal phasing.

8. The method of claim **1** further including the step of locating said controller remotely from at least one of said phase shifters.

9. The method of claim **8** further including the step of operatively coupling said controller to said at least one phase shifter with a wireless link.

10. The method of claim **1** further including the step of locking at least one of said phase shifters after beam elevation has been adjusted.

11. The method defined by claim 1 further including the step of differentially varying signal path lengths in the associated array of radiating elements to cause said adjustment of beam elevation.

12. The method of claim 8 wherein said controller controls at least one of said phase shifters through a telephone link.

13. The method of claim 1 wherein said controller is a personal computer.

14. The method of claim 1 further including the step of locating said controller at an antenna support structure.

15. The method of claim 1 further including the step of locating said controller remotely from an antenna support structure.

16. The method of claim 1 further including the step of adjusting at least one of said phase shifters to produce an increase in a downtilt angle of the beam or a decrease in a downtilt angle of the beam, said adjusting performed by said controller.

17. The method of claim 1 including the step of adjusting at least one of said phase shifters to produce selected different phasing of signals supplied to the associated array of radiating elements, said adjusting being performed by said controller.

18. The method of claim 1 wherein said controller adjusts by predetermined amounts phasing of signals supplied to at least one of said arrays of radiating elements.

19. The method of claim 1 wherein said controller measures a phase value of signals supplied to at least selected radiating elements.

20. The method of claim 1 wherein at least one of said phase shifters is included in a signal feed network.

21. The method of claim 5 wherein said first and second components in at least one of said phase shifters are capacitively coupled.

22. The method of claim 5 wherein at least one of said phase shifters is included in a signal feed network, and wherein the relative displacement between said first and second components adjusts a physical path length of signals in the signal feed network.

23. The method of claim 22 wherein said first and second components in at least one of said phase shifters are capacitively coupled.

24. The method of claim 5 wherein the relative displacement between said first and second components in at least one of said phase shifters adjusts a point of injection of a signal into a transmission line, said transmission line coupled to at least one of said radiating elements.

25. The method of claim 1 wherein the step of controlling at least one of said phase shifters adjusts a phasing of signals supplied to the associated array of radiating elements by varying a physical path length of certain of said signals relative to others of said signals.

26. The method of claim 25 including the step of increasing a length of a physical path of signals to at least one radiating element while simultaneously decreasing a length of a physical path of signals to at least one other radiating element, a single phase shifter performing said step of simultaneously effecting said increasing and decreasing of physical path length.

27. The method of claim 1 further including a signal feed network having a plurality of phase shifters located at different nodes in the signal feed network, said phase shifters adapted to control different groups of the radiating elements.

28. The method of claim 27 wherein at least one pair of said phase shifters includes first and second components, at least one of said components being movable with respect to the other, the method further including the step of mechanically ganging together at least one pair of said phase shifters.

29. The method of claim 28 further including the step of causing a relative displacement between said first and second components in one of said pair of phase shifters to produce a different relative displacement between said first and second components of another of said pair of phase shifters.

30. The method of claim 1 including the step of coupling a motor to said phase shifter and supplying drive signals to said motor.

31. The method of claim 30 wherein said motor is a stepper motor.

32. The method of claim 31 further including the step of supplying a predetermined number of drive pulses to said motor.

33. The method of claim 30 wherein said motor is located on an antenna which includes at least one of said arrays.

34. The method of claim 33 wherein said motor is mechanically coupled to said phase shifter and drives said phase shifter.

35. The method of claim 1 wherein the arrays each include bottom, central and top radiating elements, and wherein the step of controlling the phase shifter causes opposite polarity phase adjustments in signals supplied to said bottom and top radiating elements.

36. The method of claim 35 wherein said opposite polarity phase adjustments are equal in magnitude.

37. The method of claim 5 further including the step of capacitively coupling said first and second components and translating one of said components relative to the other of said components.

38. The method of claim 37 further including the step of telescopically coupling said first and second components.

39. The method of claim 5 further including the step of causing parallel translatory movement between said first and second components to effect said relative displacement.

40. The method of claim 1 wherein said controller is a portable or handheld device.

41. The method of claim 1 further including the step of controlling phase shifters from a hierarchy of controllers.

42. The method of claim 41 wherein the phase shifter is an electromechanical phase shifter, said electromechanical phase shifter being coupled to said hierarchy of controllers.

43. The method of claim 41 wherein said hierarchy of controllers includes at least one controller remotely located from said arrays of radiating elements.

44. A cellular base station telecommunication system comprising:

a plurality of separately driven arrays of radiating elements, said arrays of radiating elements developing independently controllable beams; and

a like plurality of variable phase shifters operatively coupled to said plurality of arrays of radiating elements and independently adjustable in beam tilt from a common controller.

45. The system of claim 44 wherein said phase shifters are each configured to adjust a beam direction.

46. The system of claim 44 wherein said phase shifters are each configured to adjust a beam downtilt.

47. The system of claim 44 wherein said phase shifters are each configured to adjust a phasing of signals supplied to the associated array of radiating elements in response to traffic demands.

48. The system of claim 44 wherein at least one of said phase shifters has first and second components, at least one of said components being moveable with respect to the

other, and wherein said controller varies a phasing of signals supplied to the associated array of the radiating elements by causing a relative displacement between said first component and said second component.

49. The system of claim 48 wherein said relative displacement is effected by drive devices selected from the group consisting of a screw drive, rack-and-pinion drive, gear drive, drive mechanism having plastic components to reduce intermodulation distortion, drive mechanism carrying signals to said electromechanical phase shifter, and a pulse-driven motor.

50. The system of claim 44 wherein said controller is operatively coupled to at least one of said phase shifters by a telephone link.

51. The system of claim 44 wherein said controller is operatively coupled to at least one of said phase shifters by a wireless link.

52. The system of claim 51 wherein said wireless link is a radio link.

53. The system of claim 44 further including a phase shifter lock.

54. The system of claim 44 wherein said controller is a personal computer.

55. The system of claim 44 further including an antenna support structure, and wherein said controller is located at said support structure.

56. The system of claim 44 further including an antenna support structure, and wherein said controller is located remotely from said support structure.

57. The system of claim 44 wherein said controller is adapted to adjust a phasing of signals supplied to a selected array of radiating elements so as to cause a change in beam elevation.

58. The system of claim 44 wherein said controller is adapted to select a predetermined phasing of signals supplied to a selected array of radiating elements.

59. The system of claim 44 wherein said controller is adapted to change by predetermined amounts a phasing of signals supplied to a selected array of radiating elements.

60. The system of claim 44 wherein said controller is adapted to measure a phase value of signals supplied to a selected array of radiating elements.

61. The system of claim 44 wherein said controller is adapted to identify a status of a selected beam.

62. For use in a cellular base station telecommunication system having a plurality of separately driven arrays of radiating elements developing independently controllable beams, and a like plurality of variable phase shifters operatively coupled to said plurality of arrays of radiating elements, a control arrangement operatively coupled to said plurality of phase shifters and configured to independently adjust the elevation of said plurality of beams.

63. The apparatus of claim 62 further including in said control arrangement a controller located remotely from said plurality of arrays of radiating elements.

64. The antenna control arrangement of claim 63 wherein said controller is a personal computer.

65. The antenna control arrangement of claim 63 wherein said controller is a portable or handheld device.

66. An antenna control arrangement for use in or with a cellular base station telecommunication system, the control arrangement comprising a plurality of variable phase shifters coupled to a like plurality of separately driven arrays of radiating elements, wherein the antenna control arrangement independently controls the elevation of a plurality of beams developed by said plurality of arrays of radiating elements.

67. The antenna control arrangement of claim 66 further including a hierarchy of controllers.

68. The antenna control arrangement of claim 66 wherein phase shifters is electromechanical.

69. The control system of claim 67 wherein said hierarchy of controllers includes a controller located remotely from said arrays of radiating elements.

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