

JUDGE RONALD GUZMAN

UNITED STATES DISTRICT COURT  
NORTHERN DISTRICT OF ILLINOIS  
EASTERN DIVISION

MAGISTRATE JUDGE KEYS

ANDREW CORPORATION,

Plaintiff,

v.

KATHREIN, INC., SCALA DIVISION,  
KATHREIN HOLDING USA, INC., and  
KATHREIN-WERKE KG.

Defendants.

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JURY TRIAL DEMANDED

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U.S. DISTRICT COURT

**COMPLAINT**

Plaintiff, ANDREW CORPORATION, for its Complaint against the Defendants, KATHREIN, INC., SCALA DIVISION, KATHREIN HOLDING USA, INC. and KATHREIN-WERKE KG, (hereafter collectively "Kathrein") 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. On information and belief Kathrein, Inc., Scala Division is an Oregon corporation, with its principal place of business in Medford, Oregon. On information and belief, Kathrein Scala is owned by Kathrein-Werke KG.
3. On information and belief, Kathrein Holding USA, Inc. ("Kathrein Holding") is an Oregon corporation, with its principal place of business in Medford, Oregon. On information and belief, Kathrein Holding is owned by Kathrein-Werke KG.

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4. On information and belief, Kathrein-Werke KG is a German corporation, with its principal place of business in Rosenheim, Germany. On information and belief, it is also known as Kathrein GMBH.

5. 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.

6. Kathrein Scala, Kathrein Holding, and Kathrein-Werke KB are each doing business within this judicial district, subjecting them 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**

7. On March 6, 2001 United States Patent No. 6,198,458B1 ("the '458 patent") entitled "Antenna Control System," was duly and legally issued to William Emil Heinz and Mathea Martin Ernest Ehlen and assigned to Deltec Telesystems International, Limited. Since that date the patent has been assigned to Andrew Corporation. A true and correct copy is attached as Exhibit A.

8. On February 12, 2002, United States Patent No. 6,346,924 ("the '924 patent"), entitled "Antenna Control System," was duly and legally issued to William Emil Heinz and Mathea Martin Ernest Ehlen and assigned to Andrew Corporation. Since that date Andrew has been and still is the owner of the '924 patent. A true and correct copy is attached as Exhibit B.

**DEFENDANTS' INFRINGEMENT**

9. Based on information and belief, each of Kathrein Scala, Kathrein Holding, and Kathrein-Werke KG has been and still is infringing the '458 or '924 patents by making, selling, or using devices embodying the patented inventions or inducing the infringement by others of the '458 or '924 patents and each will continue to do so unless enjoined by this Court.

**THE HARM TO ANDREW**

10. Upon information and belief, each of Kathrein Scala, Kathrein Holding, and Kathrein-Werke KG has, by their infringing conduct and their inducement of infringement by others, caused Andrew irreparable harm for which there is no adequate remedy at law.

11. Upon information and belief, each of Kathrein Scala, Kathrein Holding, and Kathrein-Werke KG has engaged in its conduct wilfully and in complete disregard of, or with indifference to Andrew's rights and interests.

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

13. 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 each of Kathrein Scala, Kathrein Holding, and Kathrein-Werke KG and their 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 '458 or '924 patents.

2. Issue an order directing each of Kathrein Scala, Kathrein Holding, Kathrein-Werke KG and Kathrein GMBH and their 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 '458 or '924 patent.

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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US006198458B1

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

(10) **Patent No.:** **US 6,198,458 B1**  
 (45) **Date of Patent:** **Mar. 6, 2001**

(54) **ANTENNA CONTROL SYSTEM**

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

(73) **Assignee:** **Deltac Telesystems International**  
**Limited, Wellington (NZ)**

(\*) **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.:** **08/817,445**

(22) **PCT Filed:** **Oct. 16, 1995**

(86) **PCT No.:** **PCT/NZ95/00106**

§ 371 Date: **Apr. 30, 1997**

§ 102(e) Date: **Apr. 30, 1997**

(87) **PCT Pub. No.:** **WO96/14670**

**PCT Pub. Date: May 17, 1996**

(30) **Foreign Application Priority Data**

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(51) **Int. Cl.<sup>7</sup>** ..... **H01Q 21/00**

(52) **U.S. Cl.** ..... **343/853; 343/757; 343/763**

(58) **Field of Search** ..... **343/853, 757,**  
**343/763, 766, 765, 778**

(56) **References Cited**

#### U.S. PATENT DOCUMENTS

2,041,600 5/1936 Friis .  
 2,432,134 12/1947 Bagnall .  
 2,540,696 \* 2/1951 Smith, Jr. .... 250/33

2,596,966 5/1952 Lindsay, Jr. .... 250/33.63  
 2,648,000 8/1953 White ..... 250/33.53  
 2,773,254 12/1956 Engelmann .  
 2,836,814 5/1958 Nail .

(List continued on next page.)

#### FOREIGN PATENT DOCUMENTS

3322-986 6/1983 (DE) .  
 3323-234 6/1983 (DE) .  
 137-562 10/1983 (EP) .  
 241-153 4/1986 (EP) .  
 357-165 8/1988 (EP) .  
 398-637 5/1989 (EP) .  
 423-512 10/1989 (EP) .  
 588179-A1 9/1992 (EP) .  
 0 595 726 5/1994 (EP) .  
 2 581 255 10/1986 (FR) .

(List continued on next page.)

#### OTHER PUBLICATIONS

B. Y. Mills, R.E. Atchison, S.M.I.R.E. (Aust.), A.G. Little  
 and W. B. BeAdam, "The Sydney University Cross-type  
 Radio Telescope", *Proceedings of the I.R.E. Australia*, pp.  
 156-165.

*Primary Examiner*—Son T. Dinh

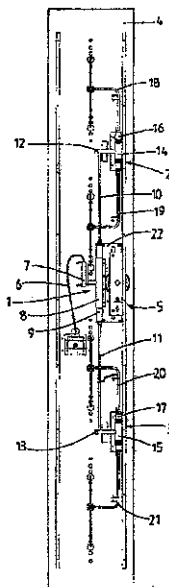
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(57) **ABSTRACT**

An antenna control system enabling the remote variation of  
 antenna beam tilt. A drive means (5, 30) continuously  
 adjusts phase shifters (1, 2, 3; 36, 39, 40) of a feed  
 distribution network to radiating elements to continuously  
 vary antenna beam tilt. A controller (80) 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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**U.S. PATENT DOCUMENTS**

2,968,808	1/1961	Russell .....	343/854
3,032,759	5/1962	Ashby .	
3,032,763	5/1962	Sletten .	
3,969,729	7/1976	Nemit .....	343/756
4,129,872	12/1978	Toman .....	343/768
4,241,352	12/1980	Alsbaugh et al. ....	343/700
4,427,984	1/1984	Anderson .....	343/764
4,532,518	7/1985	Gaglione et al. ....	343/372
4,564,824	1/1986	Boyd Jr. ....	333/137
4,575,697	3/1986	Rao et al. ....	333/157
4,652,887 *	3/1987	Cresswell .....	343/766
4,714,930 *	12/1987	Winter et al. ....	343/786
4,717,918	1/1988	Finken .....	342/368
4,768,001	8/1988	Chan-Son-Lint et al. ....	333/159
4,788,515	11/1988	Wong et al. ....	333/160
4,791,428	12/1988	Anderson .....	343/758
4,804,899 *	2/1989	Wurdack et al. ....	318/600
4,814,774	3/1989	Herczfeld .....	342/372
4,821,596 *	4/1989	Eklund .....	74/479
5,162,803	11/1992	Chen .....	342/372
5,181,042	1/1993	Kaise et al. ....	343/700
5,184,140	2/1993	Hariu et al. ....	342/372
5,214,364 *	5/1993	Perdue et al. ....	318/600
5,281,974	1/1994	Kuramoto et al. .	

5,512,914 *	4/1996	Hadzoglou et al. ....	343/816
5,801,600	9/1998	Butland et al. ....	333/127

**FOREIGN PATENT DOCUMENTS**

2 035 700	6/1980	(GB) .
2 158 996	11/1985	(GB) .
2 159 333	11/1985	(GB) .
2 165 397	4/1986	(GB) .
2 196 484	4/1988	(GB) .
2 205 946	12/1988	(GB) .
2 232 536	12/1990	(GB) .
61-172411 *	4/1986	(JP) .
61-172411	8/1986	(JP) .
1-120906	8/1989	(JP) .
2-121504	5/1990	(JP) .
2-174402	7/1990	(JP) .
2-290306	2/1991	(JP) .
4-286407	10/1992	(JP) .
5-121915	5/1993	(JP) .
5-191129	7/1993	(JP) .
6-196927	10/1994	(JP) .
WO 95/10862 *	4/1995	(NZ) .
WO 88/0862	11/1988	(WO) .
WO 95/10862	4/1995	(WO) .

\* cited by examiner

U.S. Patent

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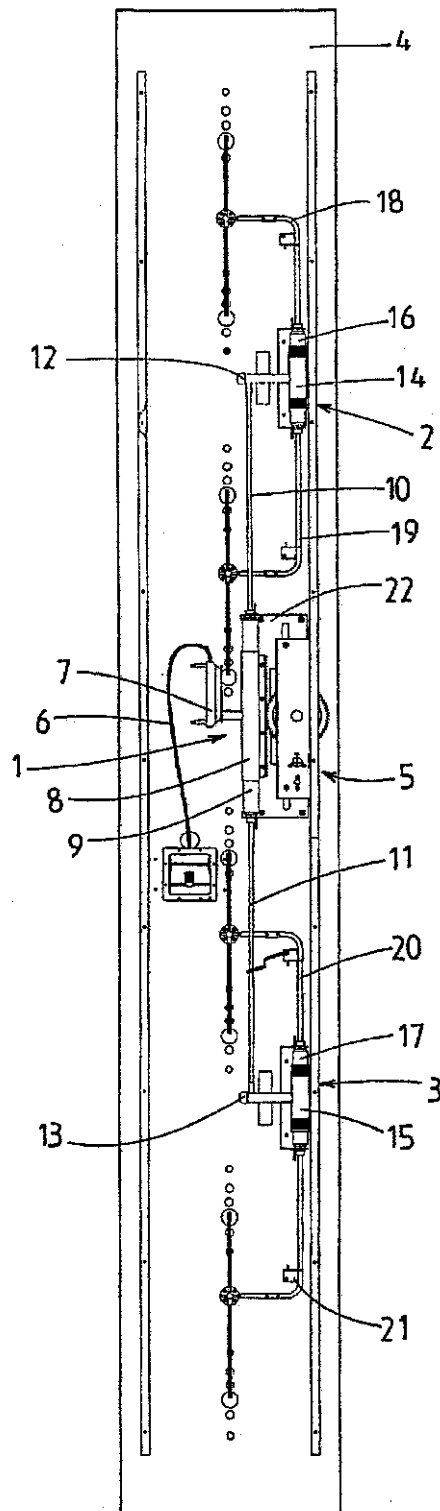


FIG.1

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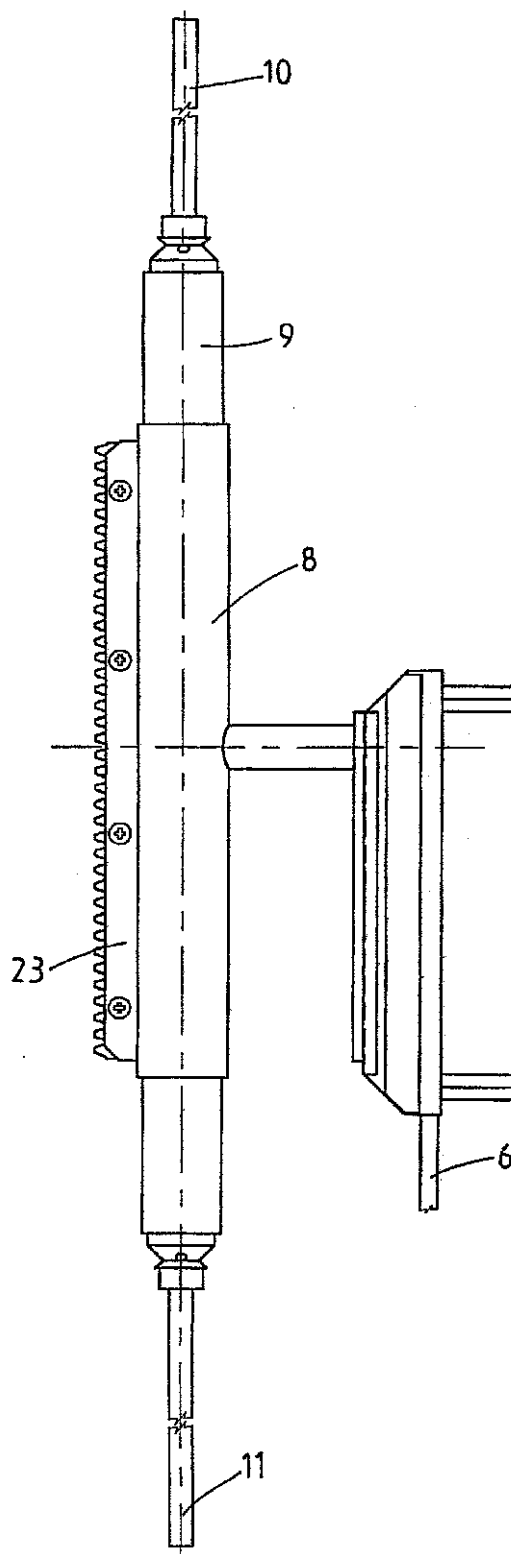


FIG. 2

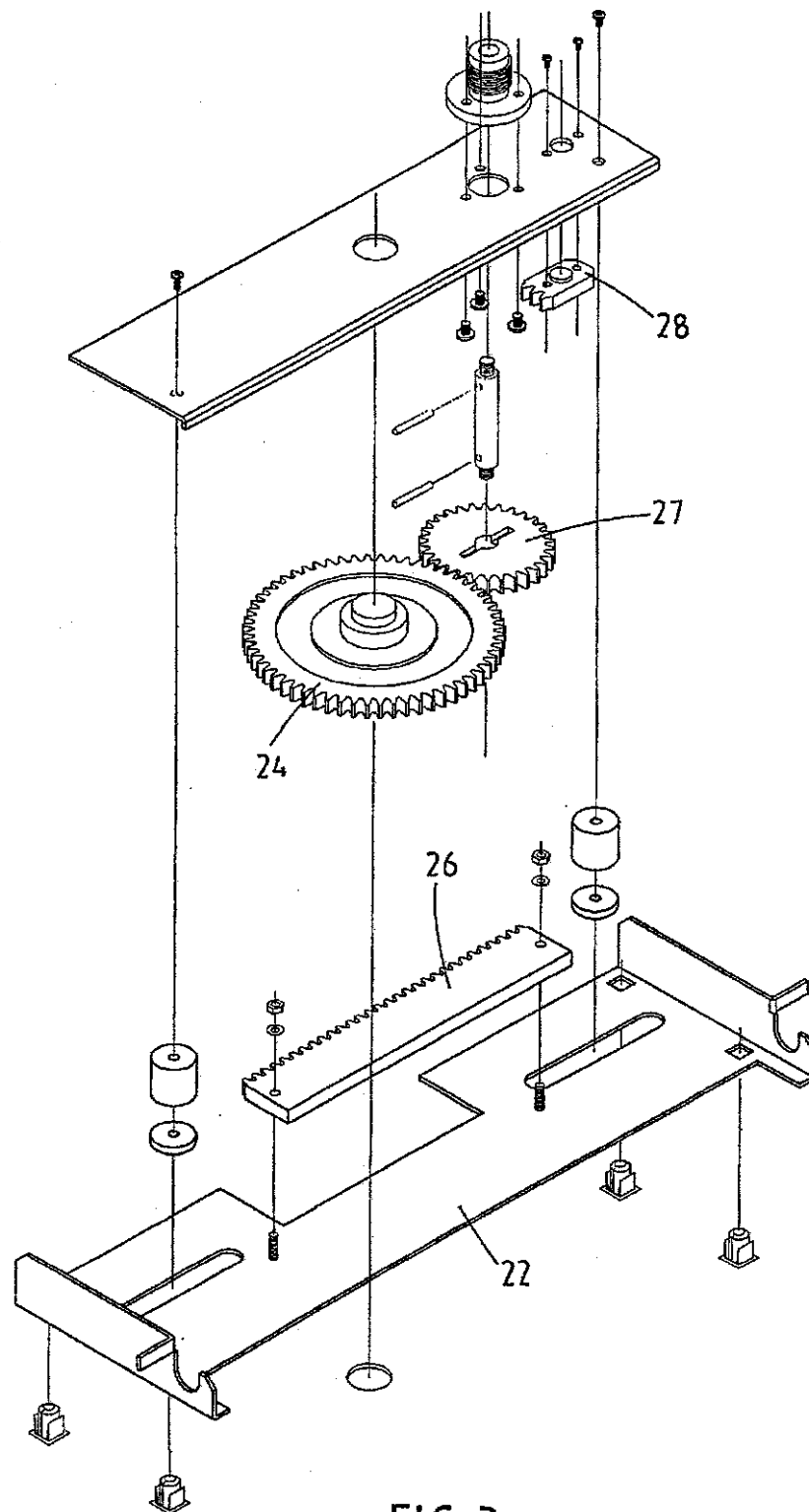


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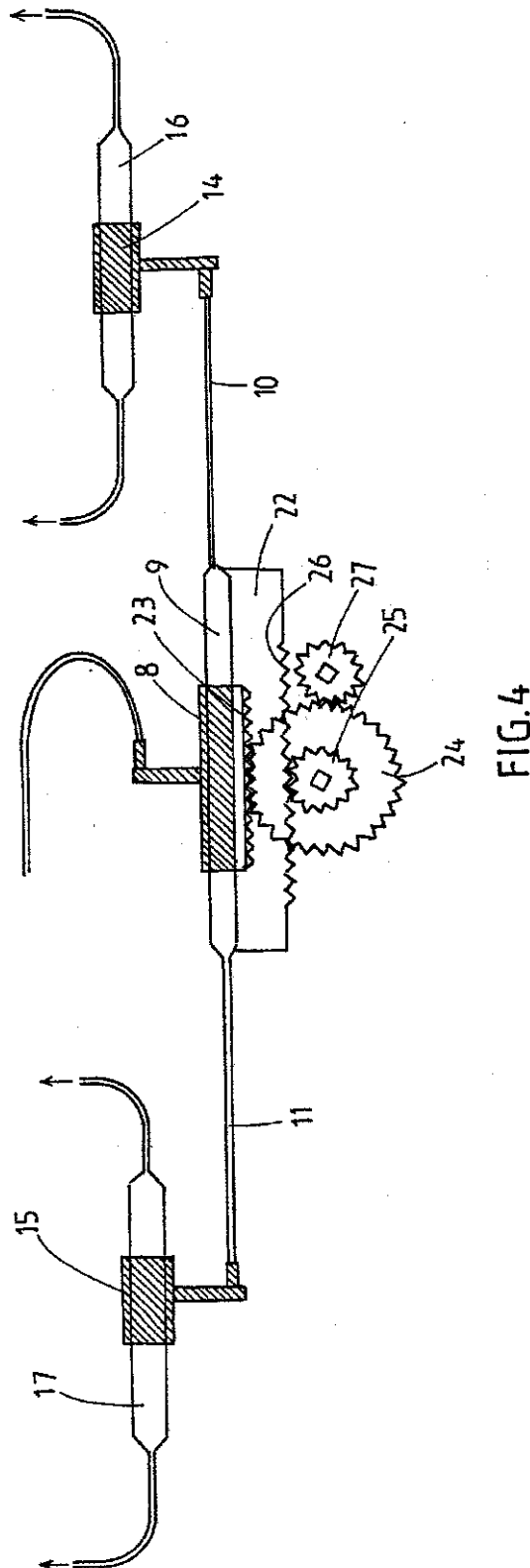
**FIG. 3**

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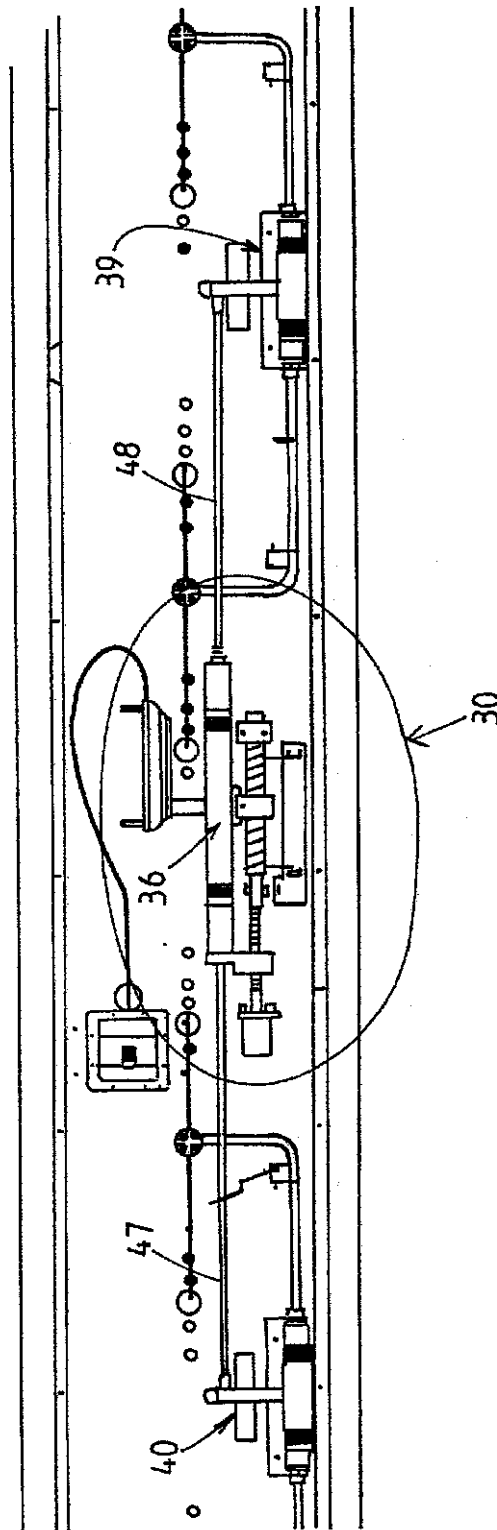


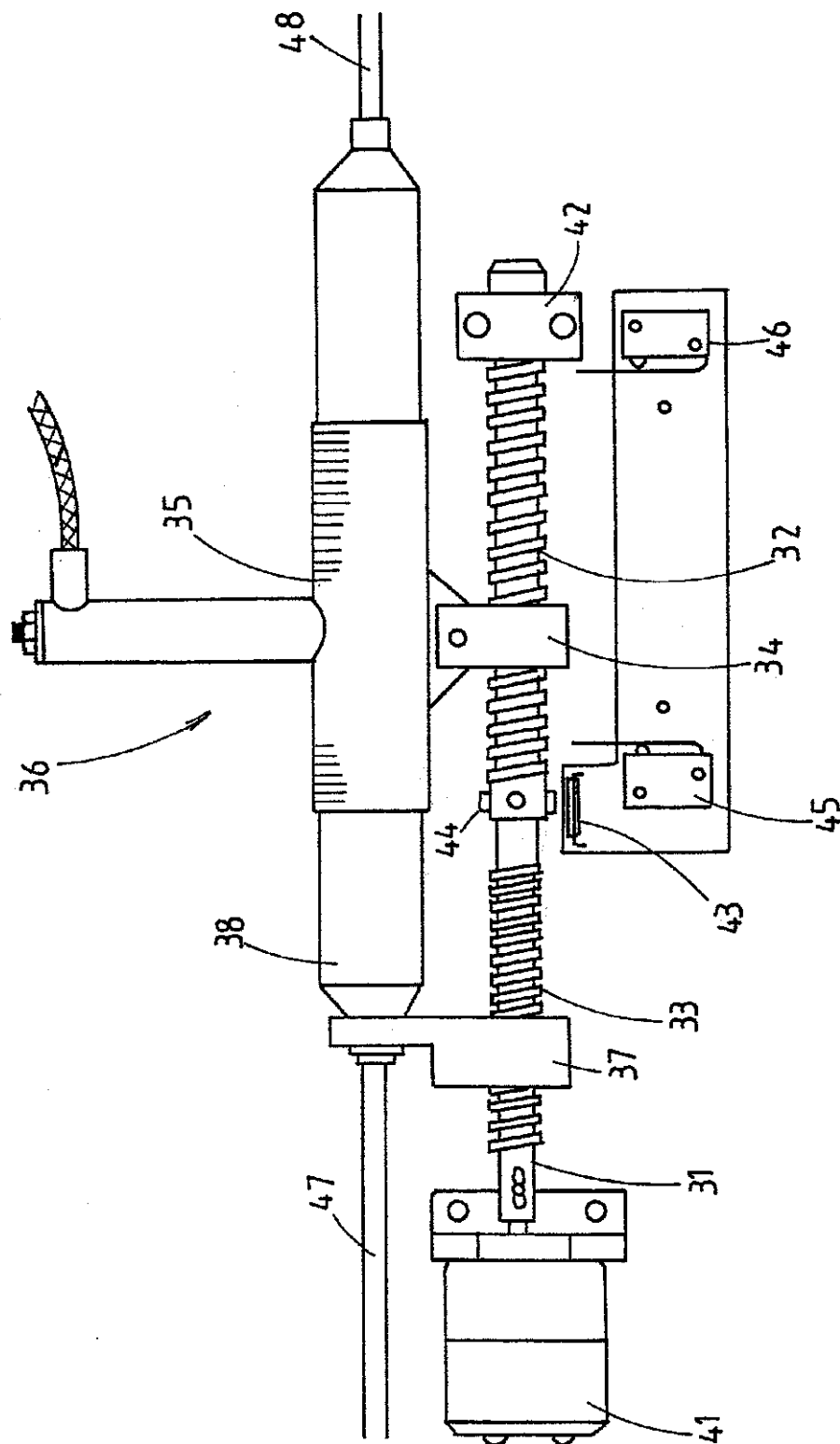
FIG. 5

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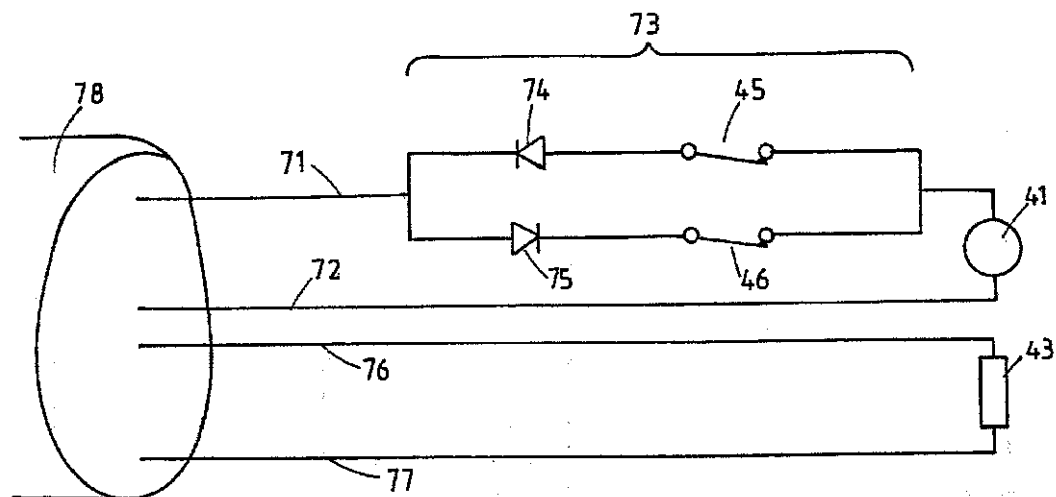


FIG. 7

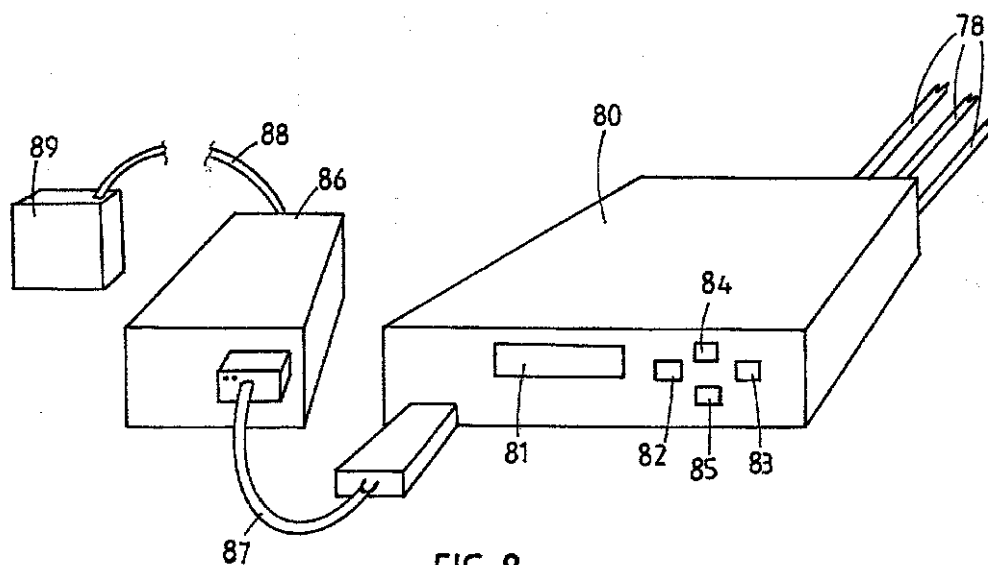


FIG. 8

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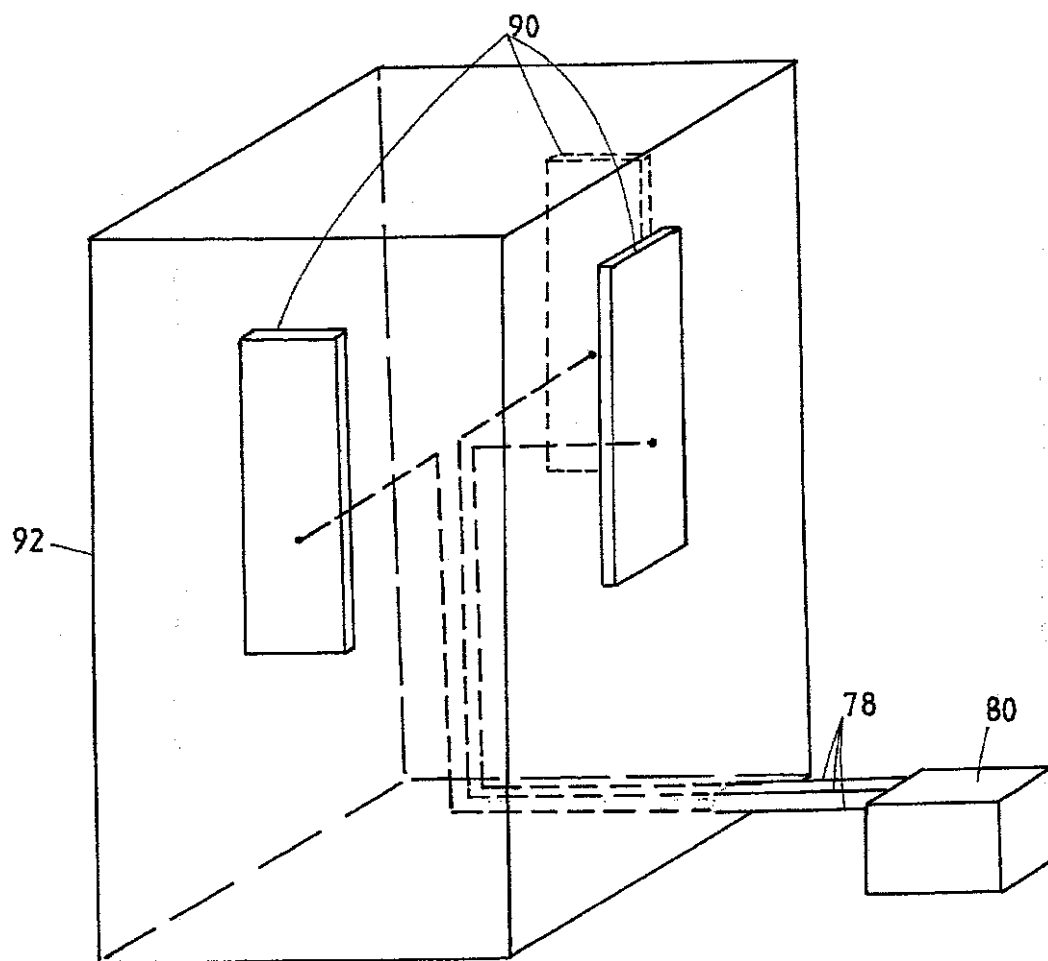


FIG. 9

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**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

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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. 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 or the second phase shifter.

According to a further aspect of the invention there is provided an antenna system comprising:

two or more antenna, each having two or more radiating means and electromechanical means for relatively

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moving components of one or more phase shifting element to vary the phase of signals supplied to the respective radiating elements to vary downtilt of the beam of the antenna;

a controller for supplying drive signals to the electromechanical means to adjust the downtilt of the beam of each antenna independent of the other(s)

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. 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:

two or more antenna, each having two or more radiating means and electromechanical means for relatively moving components of one or more phase shifting element to vary the phase of signals supplied to the respective radiating elements to vary downtilt of the beam of the antenna;

a controller for supplying drive signals to the electromechanical means to adjust the downtilt of the beam of each antenna independent of the other(s).

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.

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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 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



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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

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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 decrease 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 opens 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

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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 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

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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 travelled. 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	VT01	12°	12.5°	queued

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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	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.

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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. Drive means for adjusting relative phase shifts produced by a plurality of phase shifters connected to an array of radiating elements, said drive 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 degree of movement of the second means is dependent upon degree of movement of the first means.

2. The drive means as claimed in claim 1 wherein movement of the second means causes 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.

3. The drive means as claimed in claim 2 wherein 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 adjust the phase shifters.

4. The drive means as claimed in claim 2 wherein 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.

5. The drive means as claimed in claim 2 wherein the first means includes a first gear wheel which drives a rack connected to the 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.

6. The drive means as claimed in claim 5, wherein 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.

7. The drive means as claimed in claim 5, wherein a second gear wheel is provided, driven with the first gear wheel, which drives a rack connected to the second portion of the first phase shifter so that rotation of the second gear wheel 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.

8. The drive means as claimed in claim 7 wherein the ratio between the first and second gear wheels is about 3:1.

9. The drive means as claimed in claim 1 wherein the drive means includes a shaft and said first means includes a first threaded portion provided on said shaft and a first

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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 being 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 that is a multiple of the movement of the first portion of the second phase shifter relative to the second portion of the second phase shifter.

10. The drive means as claimed in claim 9 wherein the multiple is about 2.

11. The drive means as claimed in claim 9 wherein 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.

12. The drive means as claimed in claim 11 wherein the push rod is a coaxial line connecting an output from the first phase shifter to the input to the second phase shifter.

13. The drive means as claimed in claim 9 including 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.

14. An antenna suitable for use in a cellular communication system, the antenna comprising:

two or more radiating elements and electromechanical means responsive to externally supplied drive signals for relatively moving components of one or more phase shifting elements to vary the phase of signals supplied to the respective radiating elements to vary beam tilt of the beam of the antenna.

15. An antenna as claimed in claim 14 wherein the one or more phase shifting elements are differential phase shifters.

16. An antenna as claimed in claim 14, further comprising a controller for supplying the drive signals to the electromechanical means and wherein the electromechanical means maintains relative positions of the components of each phase shifting element in the absence of the drive signals from the controller.

17. An antenna system comprising a plurality of antennas as claimed in claim 14 and a controller for supplying the drive signals to the electromechanical means to adjust the beam tilt of the beam of the antennas.

18. An antenna system as claimed in claim 17 including measuring means to measure movement of the electromechanical means corresponding to changes in the beam tilt of each antenna.

19. An antenna system as claimed in claim 18 wherein said controller stores a value corresponding to the beam tilt of each antenna, which value is varied in accordance with information received from said measuring means.

20. An antenna system as claimed in claim 19 wherein said controller includes a table indicating the beam tilt of each antenna for a given value stored in said controller.

21. An antenna system as claimed in claim 19 wherein the controller is adapted to communicate said value to an external device.

22. An antenna system as claimed in claim 17 wherein the controller is adapted to receive commands from an external source and adjust each of said electromechanical means in accordance with such commands.

23. An antenna system as claimed in claim 22 wherein the controller includes a modem to enable communication of data and commands between the antenna system and a central control means.

24. An antenna system as claimed in claim 17 wherein the controller is detachable from the antenna system and portable.

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25. An antenna system as claimed in claim 17 wherein the electromechanical means includes a drive 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 degree of movement of the second means is dependent upon degree of movement of the first means.

26. An antenna system as claimed in claim 17 wherein the controller can adjust the beam tilt of each antenna independently of the other antennas.

27. A communication structure comprising a support structure and an antenna system as claimed in claim 17 wherein the controller is provided at a base of the support structure.

28. A communication system comprising a plurality of antenna systems as claimed in claim 17 located at a plurality of sites, each controller being responsive to commands sent from a central control means to vary the downtilt of the beam of each antenna of the antenna system.

29. An antenna system comprising one or more antenna, each having two or more radiating elements and electromechanical means responsive to externally supplied drive signals for relatively moving components of one or more phase shifting elements to vary the phase of signals supplied to the respective radiating elements to vary beam tilt of the beam of the antenna; and a portable controller for supplying drive signals to the electromechanical means.

30. An antenna system according to claim 29 wherein the antenna is suitable for use in a cellular communication system.

31. An antenna system as claimed in claim 29 wherein the one or more phase shifting elements are differential phase shifters.

32. An antenna system as claimed in claim 29 wherein the electromechanical means maintains the relative positions of the components of each phase shifting element in the absence of drive signals from the controller.

33. An antenna system as claimed in claim 29 comprising a plurality of antennas, wherein said controller supplies drive signals to the electromechanical means to adjust the beam tilt of the beam of each of the antennas.

34. An antenna system as claimed in claim 29 including measuring means to measure movement of the electromechanical means corresponding to changes in beam tilt of each antenna.

35. An antenna system as claimed in claim 34 wherein said controller stores a value corresponding to the beam tilt of each antenna, which value is varied in accordance with information received from said measuring means.

36. An antenna system as claimed in claim 35 wherein said controller includes a table indicating the beam tilt of each antenna for a given value stored in said controller.

37. An antenna system as claimed in claim 35 wherein the controller is adapted to communicate said value to an external device.

38. An antenna system as claimed in claim 29 wherein the controller is adapted to receive commands from an external source and adjust each electromechanical means in accordance with such commands.

39. An antenna system as claimed in claim 38 wherein the controller includes a modem to enable communication of data commands between the antenna system and a central control means.

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40. An antenna system as claimed in claim 29 wherein the controller is a portable control unit which can be plugged into a connector to supply said drive signals.

41. An antenna system as claimed in claim 29 wherein the electromechanical means includes a drive 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.

42. An antenna system as claimed in claim 33 wherein the controller can adjust the beam tilt of each antenna independently of the other antennas.

43. A communication structure comprising a support structure and an antenna system as claimed in claim 29 wherein the controller is provided at the base of the support structure.

44. A communication system comprising a plurality of antenna systems as claimed in claim 29 located at a plurality of sites, each controller being responsive to commands sent from a central control means to vary the downtilt of the beam of each antenna of the antenna system.

45. A method of varying the beam tilt of an antenna, the method comprising supplying a drive signal to the antenna from a portable controller; and relatively moving components of one or more phase shifting elements in response to the drive signal to vary the phase of signals supplied to respective radiating elements.

46. A method according to claim 45 comprising supplying drive signals from said controller to vary the beam tilt of a plurality of antennas.

47. A method according to claim 46 comprising remotely controlling a plurality of said controllers from a control centre.

48. A method according to claim 45 wherein the relative movement of the phase shifting elements causes a change in path length of the signals supplied to the respective radiating elements.

49. An antenna according to claim 14 wherein the relative movement of the phase shifting elements causes a change in path length of the signals supplied to the respective radiating elements.

50. An antenna system according to claim 29 wherein the relative movement of the phase shifting elements causes a change in path length of the signals supplied to the respective radiating elements.

51. An antenna system comprising two or more antenna, each having two or more radiating elements and electromechanical means responsive to externally supplied drive signals for relatively moving components of one or more phase shifting elements to vary the phase of signals supplied to the respective radiating elements to vary beam tilt of the beam of the antenna; and a controller for supplying drive signals to the electromechanical means.

52. An antenna system according to claim 51 wherein the antenna is suitable for use in a cellular communication system.

53. An antenna system as claimed in claim 51 wherein the one or more phase shifting elements are differential phase shifters.

54. An antenna system as claimed in claim 51 wherein the electromechanical means maintains the relative positions of the components of each phase shifting element in the absence of drive signals from the controller.

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55. An antenna system as claimed in claim 51 including measuring means to measure movement of the electromechanical means corresponding to changes in beam tilt of each antenna.

56. An antenna system as claimed in claim 51 wherein said controller stores a value corresponding to the beam tilt of each antenna, which value is varied in accordance with information received from said measuring means.

57. An antenna system as claimed in claim 56 wherein said controller includes a table indicating the beam tilt of each antenna for a given value stored in said controller.

58. An antenna system as claimed in claim 56 wherein said controller is adapted to communicate said value to an external device.

59. An antenna system as claimed in claim 51 wherein said controller is adapted to receive commands from an external source and adjust each electromechanical means in accordance with such commands.

60. An antenna system as claimed in claim 51 wherein said controller includes a modem to enable communication of data commands between the antenna system and a central control means.

61. An antenna system as claimed in claim 51 wherein said controller is portable.

62. An antenna system as claimed in claim 61 wherein said controller is a portable control unit which can be plugged into a connector to supply said drive signals.

63. An antenna system as claimed in claim 51 wherein the electromechanical means includes a drive 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.

64. An antenna system as claimed in claim 51 wherein the controller can adjust the beam tilt of each antenna independently of the other antennas.

65. A communication structure comprising a support structure and an antenna system as claimed in claim 51 wherein the controller is provided at the base of the support structure.

66. A communication system comprising a plurality of antenna systems as claimed in claim 51 located at a plurality of sites, each controller being responsive to commands sent from a central control means to vary the downtilt of the beam of each antenna of the antenna system.

67. A method of varying the beam tilt of two or more antennas, the method comprising supplying drive signals to the antennas from a common controller; and relatively moving components of one or more phase shifting elements in response to the drive signals to vary the phase of signals supplied to respective radiating elements.

68. A method according to claim 67 comprising remotely controlling a plurality of said controllers from a control centre.

69. A method according to claim 67 wherein the relative movement of the phase shifting elements causes a change in path length of the signals supplied to the respective radiating elements.

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

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 (45) Date of Patent: **Feb. 12, 2002**

- (54) **ANTENNA CONTROL SYSTEM**
- (75) Inventors: **William Emil Heinz; Mathias Martin Ernest Ehlen**, both of 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.: **09/713,614**
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4,241,352 A	12/1980	Alspaugh et al.	343/700
4,427,984 A	1/1984	Anderson	343/764
4,532,518 A	7/1985	Gaglione et al.	343/372
4,564,824 A	1/1986	Boyd, Jr.	333/137
4,575,697 A	3/1986	Rao et al.	333/157
4,652,887 A	3/1987	Cresswell	343/766
4,714,930 A	12/1987	Winter et al.	343/786
4,717,918 A	1/1988	Finken	342/368
4,768,001 A	8/1988	Chan-Son-Lint et al.	333/159
4,788,515 A	11/1988	Wong et al.	333/160
4,791,428 A	12/1988	Anderson	343/758
4,804,899 A	2/1989	Wurdack et al.	318/600
4,814,774 A	3/1989	Herczfeld	342/372
4,821,596 A	4/1989	Eklund	74/479
5,162,803 A	11/1992	Chen	342/372
5,181,042 A	1/1993	Kaise et al.	343/700
5,184,140 A	2/1993	Hariu et al.	342/372

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(30) **Foreign Application Priority Data**

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- (58) Field of Search ..... **343/853, 757, 343/763, 766, 765, 778**

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

2,041,600 A	5/1936	Friis	
2,432,134 A	12/1947	Bagnall	
2,540,696 A	2/1951	Smith, Jr.	250/33
2,596,966 A	5/1952	Lindsay, Jr.	250/33.63
2,648,000 A	8/1953	White	250/33.53
2,773,254 A	12/1956	Englemann	
2,836,814 A	5/1958	Nail	
2,968,808 A	1/1961	Russell	343/854
3,032,759 A	5/1962	Ashby	
3,032,763 A	6/1962	Sletten	
3,969,729 A	7/1976	Nemit	343/756
4,129,872 A	12/1978	Toman	343/768

(List continued on next page.)

**FOREIGN PATENT DOCUMENTS**

AU	933874	5/1993
AU	9341625	6/1993

(List continued on next page.)

**OTHER PUBLICATIONS**

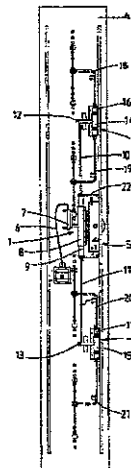
Specifications: Mobile Telephone Panel Array (MTPA) Antenna, Field Adjustable Downtilt Models; Deltec New Zealand Limited.

(List continued on next page.)

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(57) **ABSTRACT**

An antenna control system enabling the remote variation of antenna beam tilt. A drive means (5, 30) continuously adjusts phase shifters (1, 2, 3; 36, 39, 40) feed distribution network to radiating elements to continuously vary antenna beam tilt. A controller (80) enables the beam tilt of a number of antenna at a site to be remotely varied.

**15 Claims, 8 Drawing Sheets**

## US 6,346,924 B1

Page 2

## U.S. PATENT DOCUMENTS

5,214,364 A	5/1993	Perdue et al. ....	318/600
5,281,974 A	1/1994	Kuramoto et al. ....	343/700
5,440,318 A	8/1995	Butland et al.	
5,488,737 A	1/1996	Harbin et al.	
5,512,914 A	4/1996	Hadzoglou et al. ....	343/816
5,551,060 A	8/1996	Fujii et al.	
5,798,675 A *	8/1998	Drach .....	333/161
5,801,600 A	9/1998	Butland et al. ....	333/127
5,805,996 A	9/1998	Salmela	
5,818,385 A	10/1998	Bartholomew	
5,905,462 A *	5/1999	Hampel et al. ....	342/372
6,188,373 B1 *	2/2001	Martek .....	343/893

## FOREIGN PATENT DOCUMENTS

AU	9480057	10/1994
DE	3322-986 A	6/1983
DE	3323-234 A	6/1983
EP	137-562 A	10/1983
EP	241-153 A	4/1986
EP	357-165 A	8/1988
EP	398-637 A	5/1989
EP	423-512 A	10/1989
EP	588179 A1	9/1992
EP	0 618 639	3/1994
EP	0 595 726	5/1994
FR	2 581 255	10/1986
GB	1 314 693	10/1970
GB	1314693	4/1973
GB	2 035 700 A	6/1980
GB	2 158 996 A	11/1985
GB	2 159 333 A	11/1985
GB	2 165 397 A	4/1986
GB	2 196 484 A	4/1988
GB	2 205 946 A	12/1988
GB	2 232 536 A	12/1990
JP	61-172411	8/1986
JP	01-120906	8/1989

JP	02-121504	5/1990
JP	02-174402	7/1990
JP	02-290306	2/1991
JP	04-286407	10/1992
JP	05-121915	5/1993
JP	05-191129	7/1993
JP	06-196927	10/1994
WO	WO 88/08621	10/1988
WO	88/08621	11/1988
WO	WO 95/10862	4/1995

## OTHER PUBLICATIONS

Specifications: Mobile Telephone and Panel Array (MTPA) Antenna, VARITILT Continuously Variable Electrical Downtilt Models; Deltec New Zealand Limited.

B. Heath, 1993, "Design Specification for Premium Antenna with EDT and AS".

Friis, 1947, *The Bell System Technical Journal*, XXVI:218-316, "Radar Antennas".

G.E. Bacon, 1946, *Journal I.E.E.*, 93:539-544, "Variable-Elevation Beam-Aerial Systems for 1 1/2 Metres".

W.H. Kummer, *Microwave Scanning Antennas*, III:48-130, "Electromechanical Devices".

Mills et al., 1963, *Proceedings of the I.R.E. Australia*, "The Sydney University Cross-type Radio Telescope".

Gary Wilson, 1992, "Electrical Downtilt Through Beam-Steering Versus Mechanical Downtilt".

Yamada et al., NTT Radio Communication Systems Laboratories and Nippon Telegraph and Telephone Corporation, "Low Sidelobe and Tilted Beam Base-Station Antennas for Smaller-Cell Systems".

B. Y. Mills, R. E. Atchison, S.M.I.R.E. (Aust.), A.G. Little and W.B. BeAdam, "The Sydney University Cross-type Radio Telescope", *Proceedings of the I.R.E. Australia*, pp. 156-165.

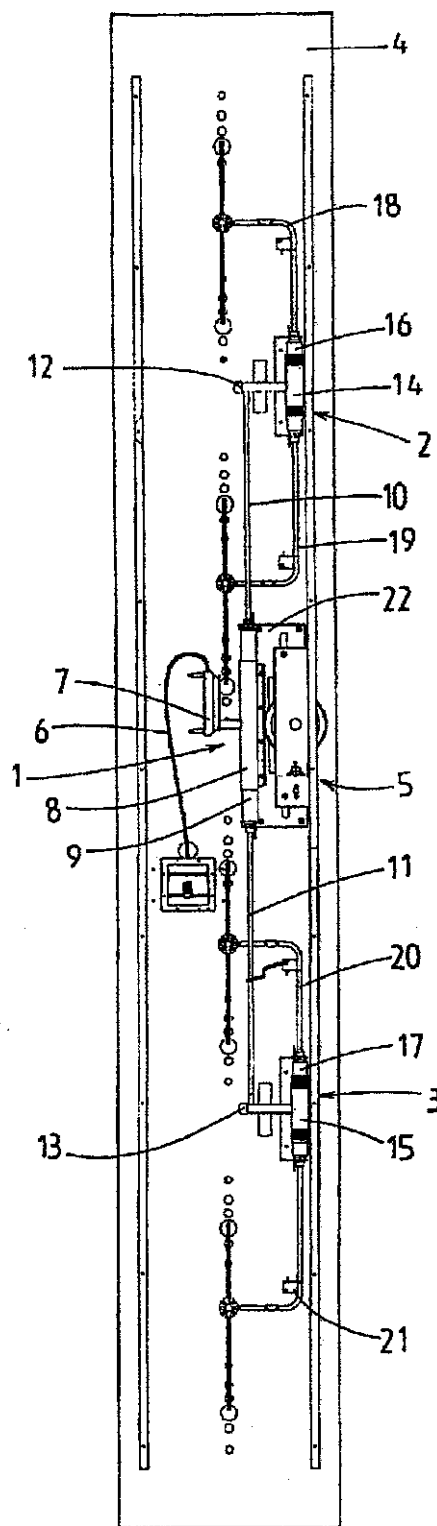
\* cited by examiner

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**FIG.1**



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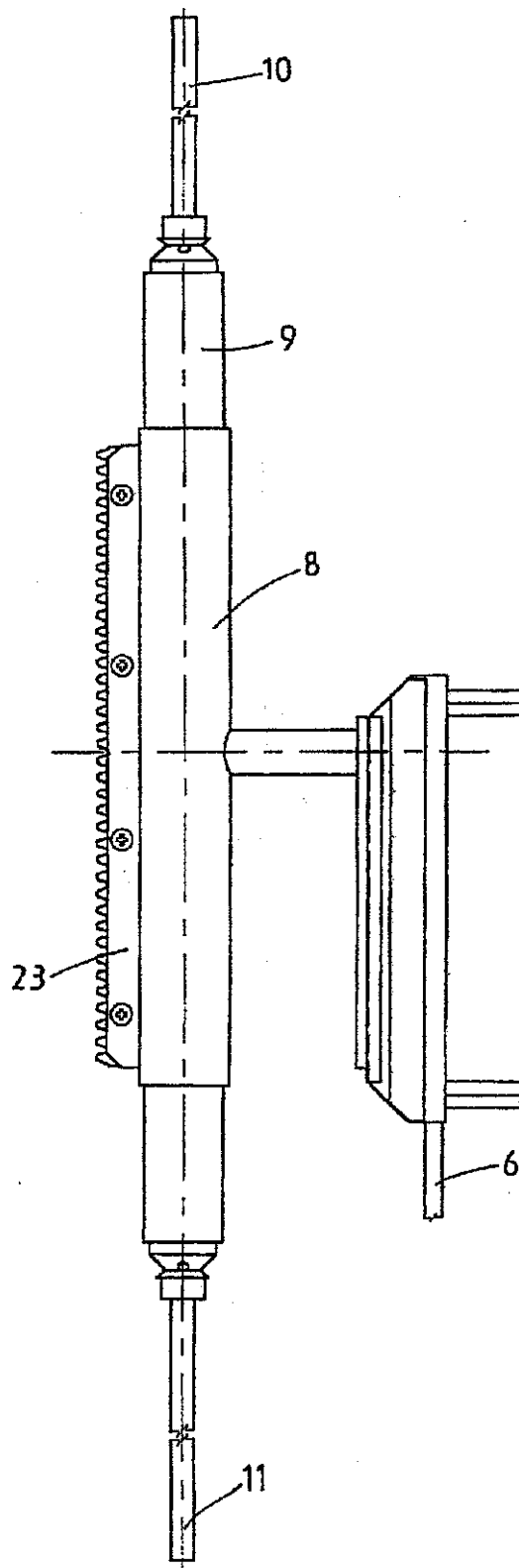


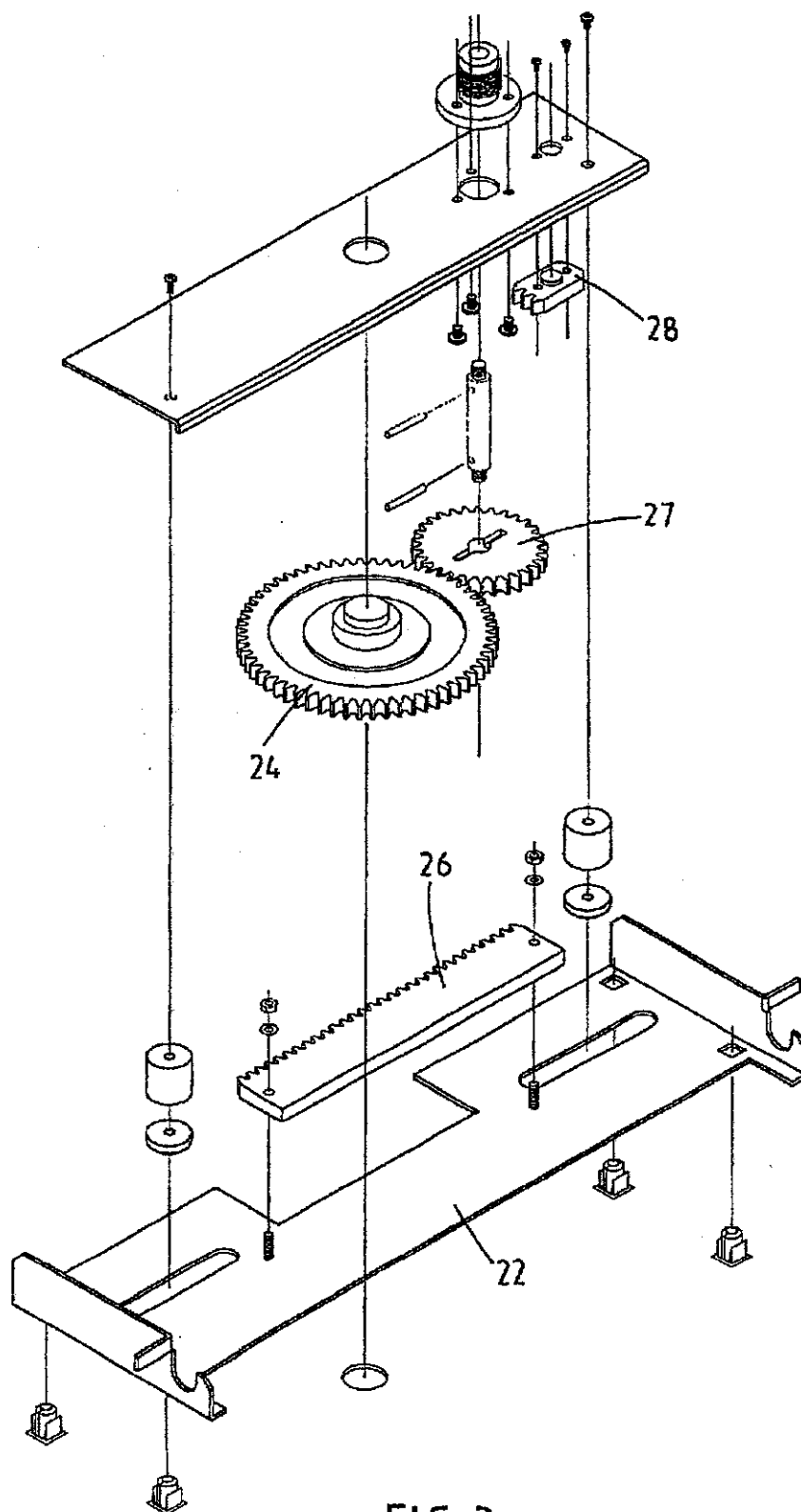
FIG. 2

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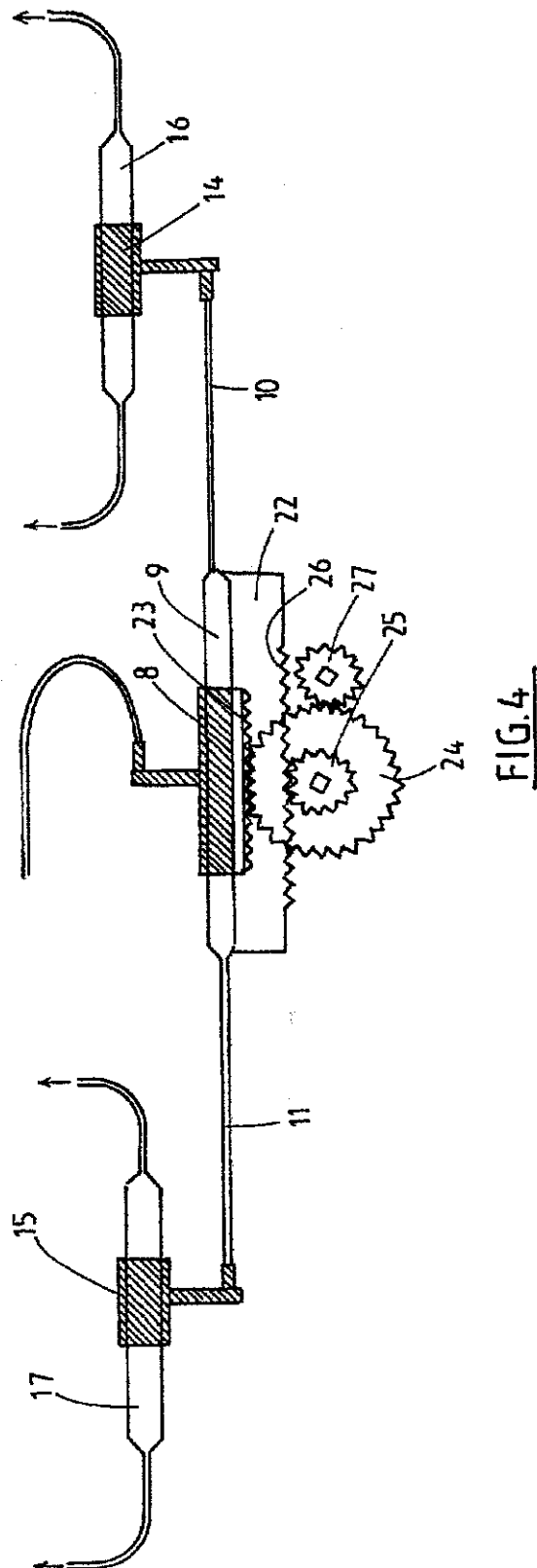
**FIG. 3**

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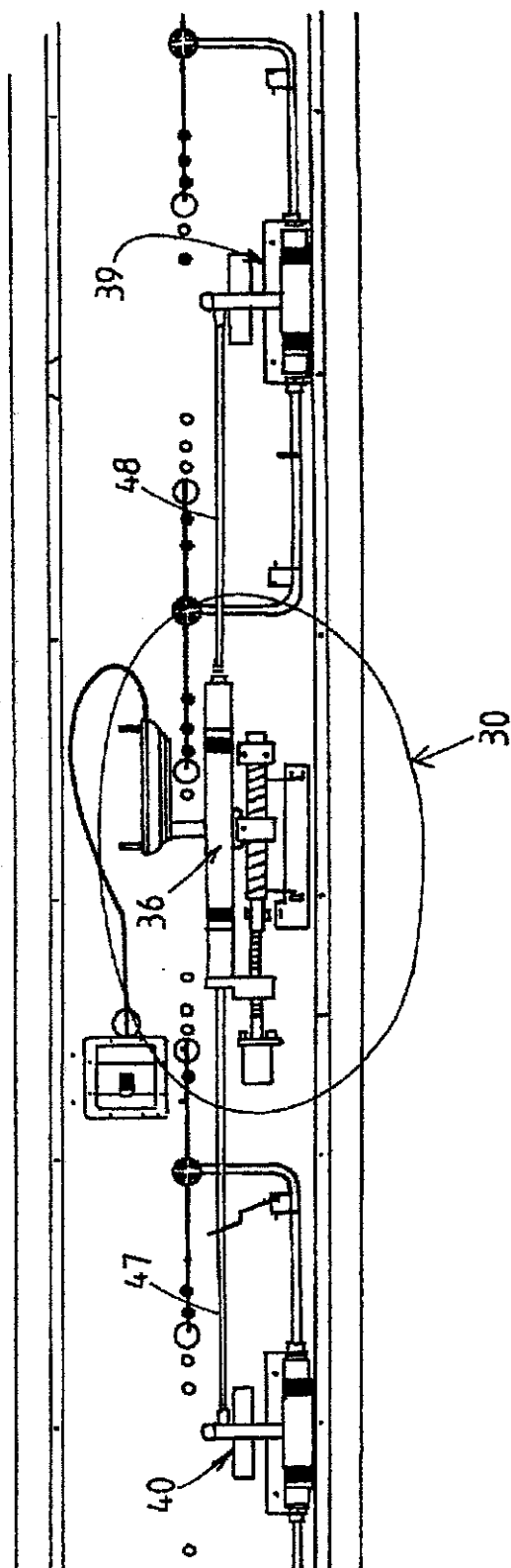


**U.S. Patent**

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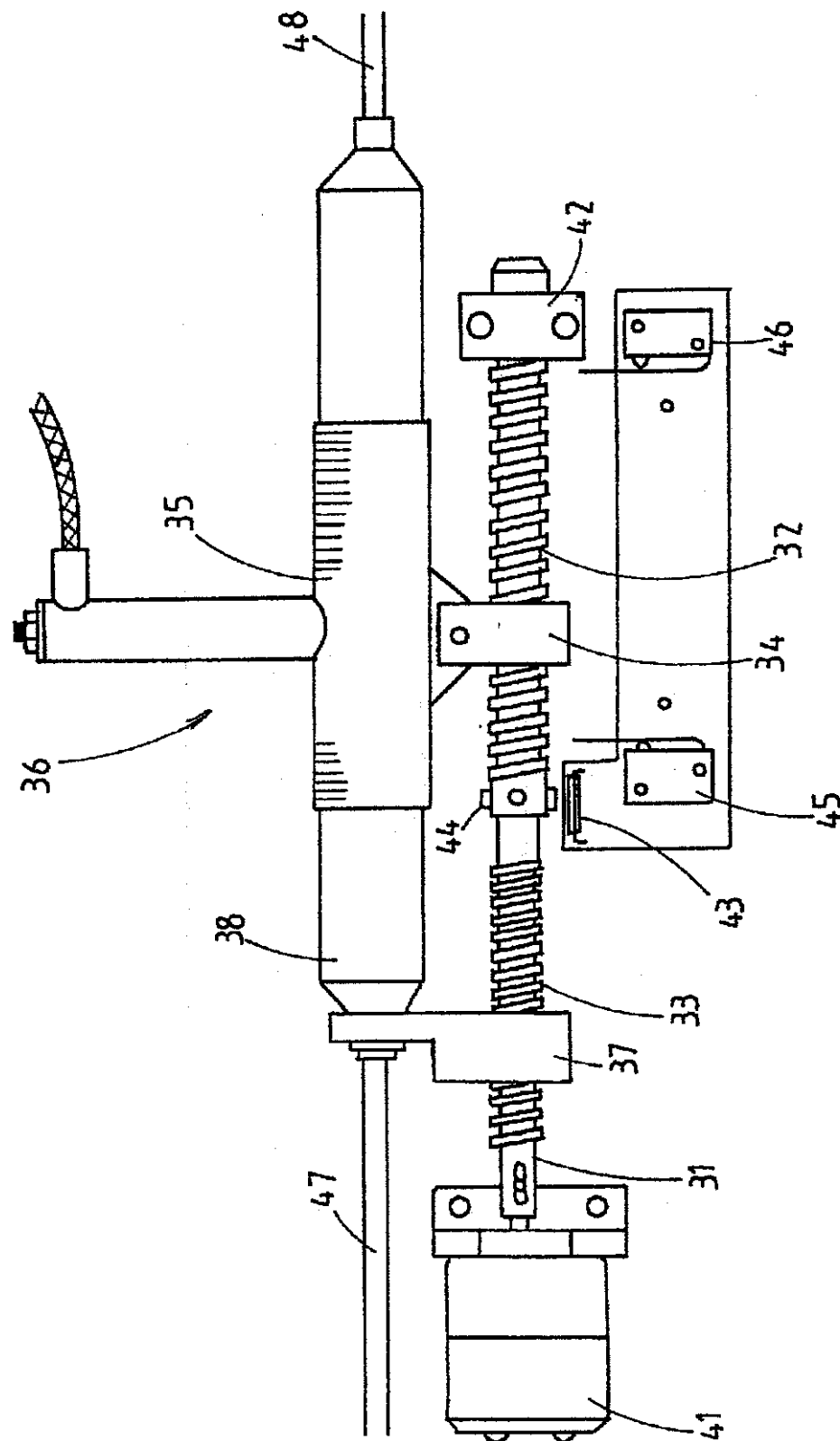
**FIG. 5**

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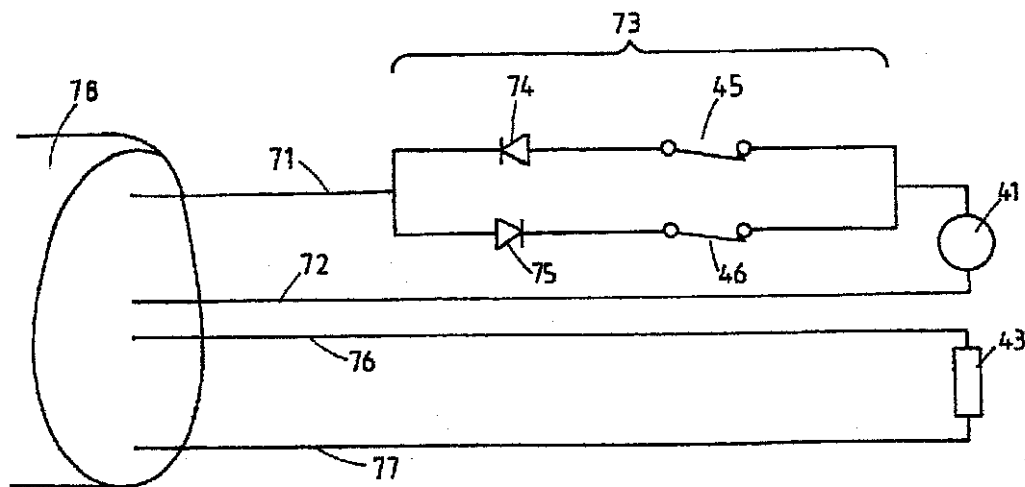


FIG. 7

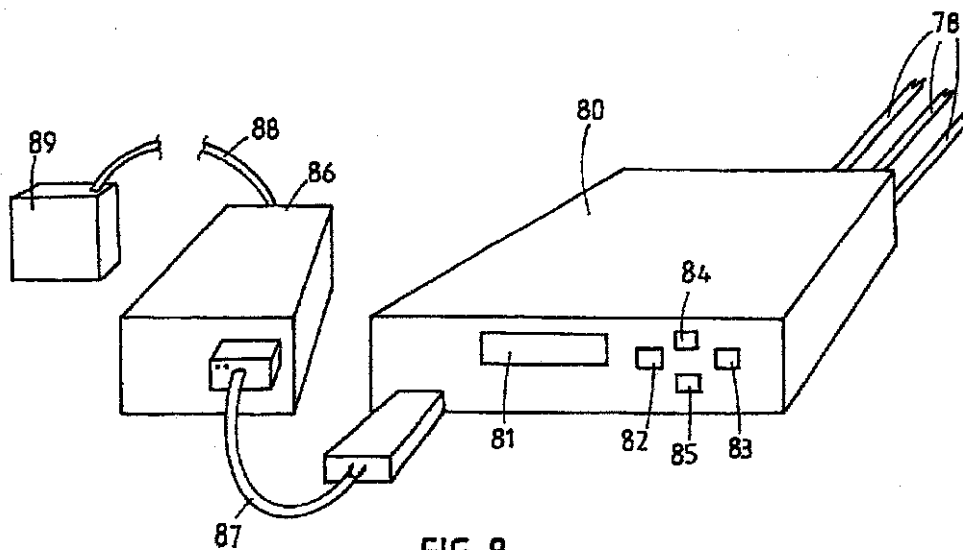


FIG. 8

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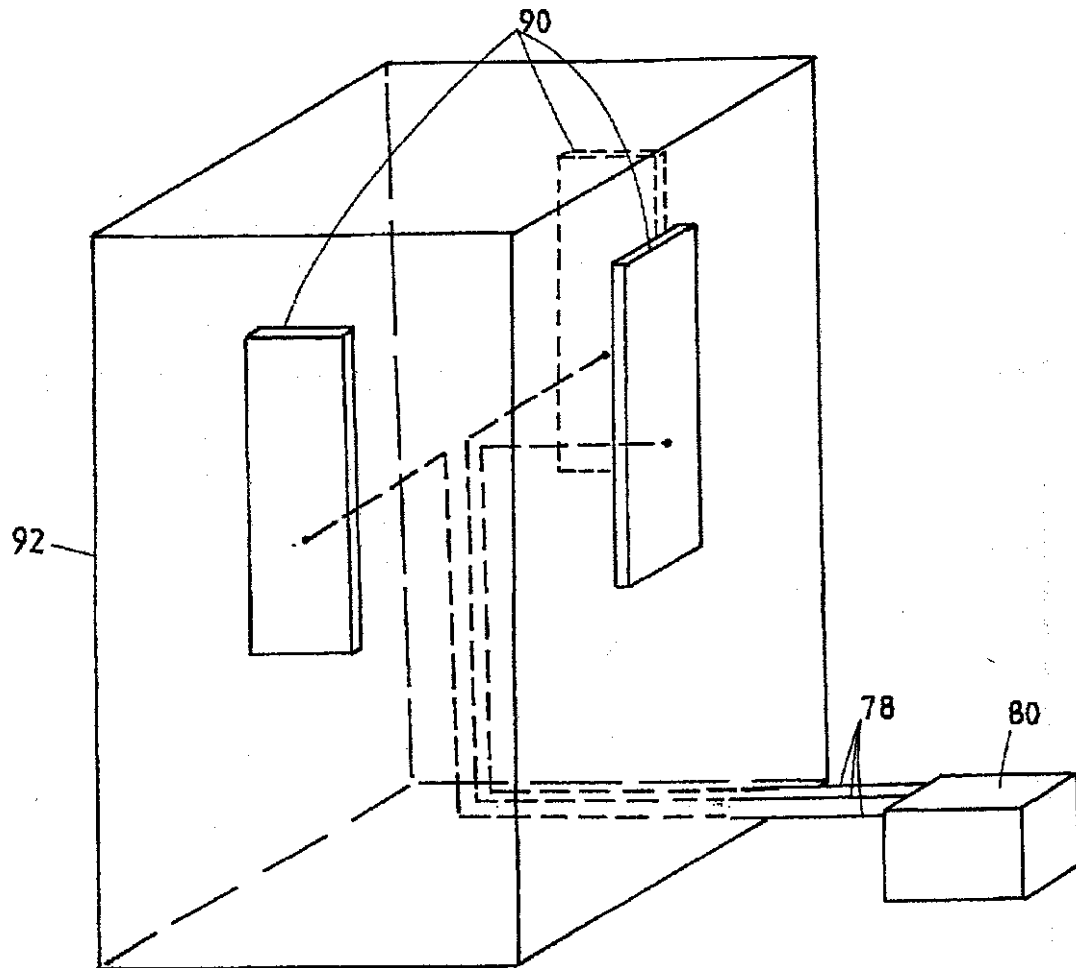


FIG. 9

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**ANTENNA CONTROL SYSTEM**

This application is a continuation of PCT National Stage application Ser. No. 08/817,445, filed Apr. 30, 1997 now U.S. Pat. No. 6,198,458, which application(s) are incorporated herein by reference.

**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

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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



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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 shifters

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 antenna and the controller may adjust the downtilt for the plurality of antenna 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 DESCRIPTIONS 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.

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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 portions 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 portions 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 phase shifter 9 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

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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 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 3. 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.

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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 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 decrease 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 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 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.

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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, member 34 may be driven to the extreme left and then back to the right.

At an antenna site a number of such panels 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 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 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 4.60°. 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.

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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 counts the number of pulses from reed switch 43 to determine how far threaded portion 34 has travelled. At the extreme right position the controller determines and displays the angle of downtilt, calculated in accordance with the number of pulses connected from reed switch 43. The controller 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 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:

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GROUP 1	NAME	TYPE ANGLE	CURRENT VALUE	NEW VALUE	STATUS
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	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	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 panel antenna, comprising:

a back panel having a back side and a front side;

a plurality of radiating elements mounted on the back panel;

a plurality of phase shifters mounted on the backside of the back panel and connected to the plurality of radiating elements; and

a drive mechanism configured to adjust the relative phase shifts produced by the plurality of phase shifters said drive mechanism including:

a first translator configured to move a first portion of a first phase shifter of the plurality of phase shifters relative to a second portion of said first phase shifter to vary the phase difference between output signals from the first phase shifter; and

a second translator configured to move a first portion of a second phase shifter of the plurality of phase shifters 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 translator is dependent upon the degree of movement of the first translator.

2. The panel antenna as claimed in claim 1 wherein movement of the second translator causes simultaneous movement of a first portion of a third phase shifter of the plurality of phase shifters 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.

3. The panel antenna as claimed in claim 2 wherein the outputs of the second and third phase shifters are connected to the plurality of radiating elements so as to produce a beam which tilts as the first and second translators adjust the phase shifters.

4. The panel antenna as claimed in claim 2 wherein 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.

5. The panel antenna as claimed in claim 2 wherein the first translator includes a first gear wheel which drives a rack connected to the first portion of the first phase shifter,

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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.

6. The panel antenna as claimed in claim 5, wherein 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.

7. The panel antenna as claimed in claim 5, wherein a second gear wheel is provided, driven with the first gear wheel, which drives a rack connected to the second portion of the first phase shifter so that rotation of the second gear wheel causes movement of the first portions of the second and third phase shifters relative to the second portions of the second and third phase shifters.

8. The panel antenna as claimed in claim 7 wherein the ratio between the first and second gear wheels is about 3:1.

9. The panel antenna as claimed in claim 1, wherein the drive mechanism includes a shaft and said first translator 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 translator 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 being 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 that is a multiple of the movement of the first portion of the second phase shifter relative to the second phase shifter.

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10. The panel antenna as claimed in claim 9 wherein the multiple is about 2.

11. The panel antenna as claimed in claim 9 wherein 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.

12. The panel antenna as claimed in claim 11 wherein the push rod is a coaxial line connecting an output from the first phase shifter to the input of the second phase shifter.

13. The panel antenna as claimed in claim 9 including a third phase shifter of the plurality of phase shifters 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.

14. A panel antenna comprising:

a back panel having a front side and a back side;

two or more radiating elements mounted on the front side of the back panel;

one or more phase shifters connected to the two or more radiating elements and mounted on the back side of the back panel; and

electromechanical means mounted on the back side of the back panel and responsive to externally supplied drive signals for relatively moving components of the one or more phase shifters to vary the phase of signals supplied to the respective radiating elements to vary beam tilt of the beam of the panel antenna.

15. An antenna system comprising a panel antenna according to claim 14, and a controller, external to the panel antenna, for supplying drive signals to the electromechanical means.

\* \* \* \* \*

**UNITED STATES DISTRICT COURT**  
**NORTHERN DISTRICT OF ILLINOIS**  
**JUDGE RONALD GUZMAN**  
**MAGISTRATE JUDGE KEYS**

## Civil Cover Sheet Input Form

This form has been approved for use by the general public for generating the civil cover sheet for filing new cases in the Northern District of Illinois. Your comments about the form and suggestions for improvements are always greatly appreciated.

**02C 3522**

**DOCKETED**

**MAY 16 2002**

This automated JS-44 conforms generally to manual JS-44 approved by the Judicial Conference of the United States in September 1974. The data is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. The information contained herein neither replaces nor supplements the filing and service of pleadings or other papers as required by law. This form is authorized for use only in the Northern District of Illinois. (Instructions)

I (a) - PLAINTIFFS		DEFENDANTS	
ANDREW CORPORATION		KATHREIN, INC., SCALA DIVISION, KATHREIN HOLDING USA, INC. KATHREIN-WERKE KG	
b) - County of Residence of First Listed Plaintiff (Except in U.S. Plaintiff Cases) Cook County		County of Residence of First Listed Defendant (In U.S. Plaintiff Cases Only)	
Plaintiff's Attorney		Defendant's Attorney (If known)	
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Firm:	Barnes & Thornburg	Firm:	
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Phone:	(312) 357-1313	Phone:	

### II. Basis of Jurisdiction

(Select from drop menu below)

3. Federal Question (U.S. not a party)

### III. Citizenship of Principal Parties (Diversity cases only)

#### PLAINTIFF

N/A

#### DEFENDANT

N/A

### IV. Origin

(Select from drop menu below)

1. Original Proceeding

### V. Nature of Suit (Select one box)

#### Contract

☐ 110 Insurance

#### Torts

#### Other Statutes

☐ 400 State Reapportionment

**UNITED STATES DISTRICT COURT  
NORTHERN DISTRICT OF ILLINOIS**

Eastern Division

**JUDGE RONALD GUZMAN**

In the Matter of

**ANDREW CORPORATION****Plaintiff,**

v.

Case Number

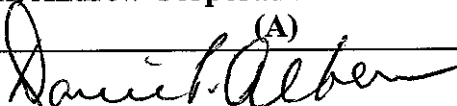
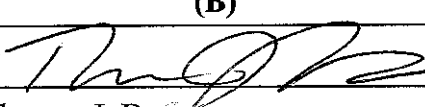
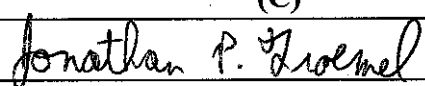
**02C 3522**

**KATHREIN, INC., SCALA DIVISION, KATHREIN  
HOLDING USA, INC. and KATHREIN-WERKE KG,  
Defendant.**

**DOCKETED**

APPEARANCES ARE HEREBY FILED BY THE UNDERSIGNED AS ATTORNEY(S) FOR: MAY 16 2002

**Plaintiff, Andrew Corporation**

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MEMBER OF TRIAL BAR? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>		MEMBER OF TRIAL BAR? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>	
TRIAL ATTORNEY? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>		TRIAL ATTORNEY? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>	
DESIGNATED AS LOCAL COUNSEL? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>		DESIGNATED AS LOCAL COUNSEL? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>	
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TRIAL ATTORNEY? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>		TRIAL ATTORNEY? YES <input type="checkbox"/> NO <input type="checkbox"/>	
DESIGNATED AS LOCAL COUNSEL? YES <input type="checkbox"/> NO <input type="checkbox"/>		DESIGNATED AS LOCAL COUNSEL? YES <input type="checkbox"/> NO <input type="checkbox"/>	

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