Aug. 1, 1967 W. A. ALFANO, JR 3,334,348

STEERABLE MONOPOLE ANTENNA SYSTEM HAVING A PLURALITY OF REFLECTORS, SAID REFLECTORS COMPRISING A SERIES OF TUBULAR VACUUM SWITCHES

Filed Nov. 25, 1966

4 Sheets-Sheet 1

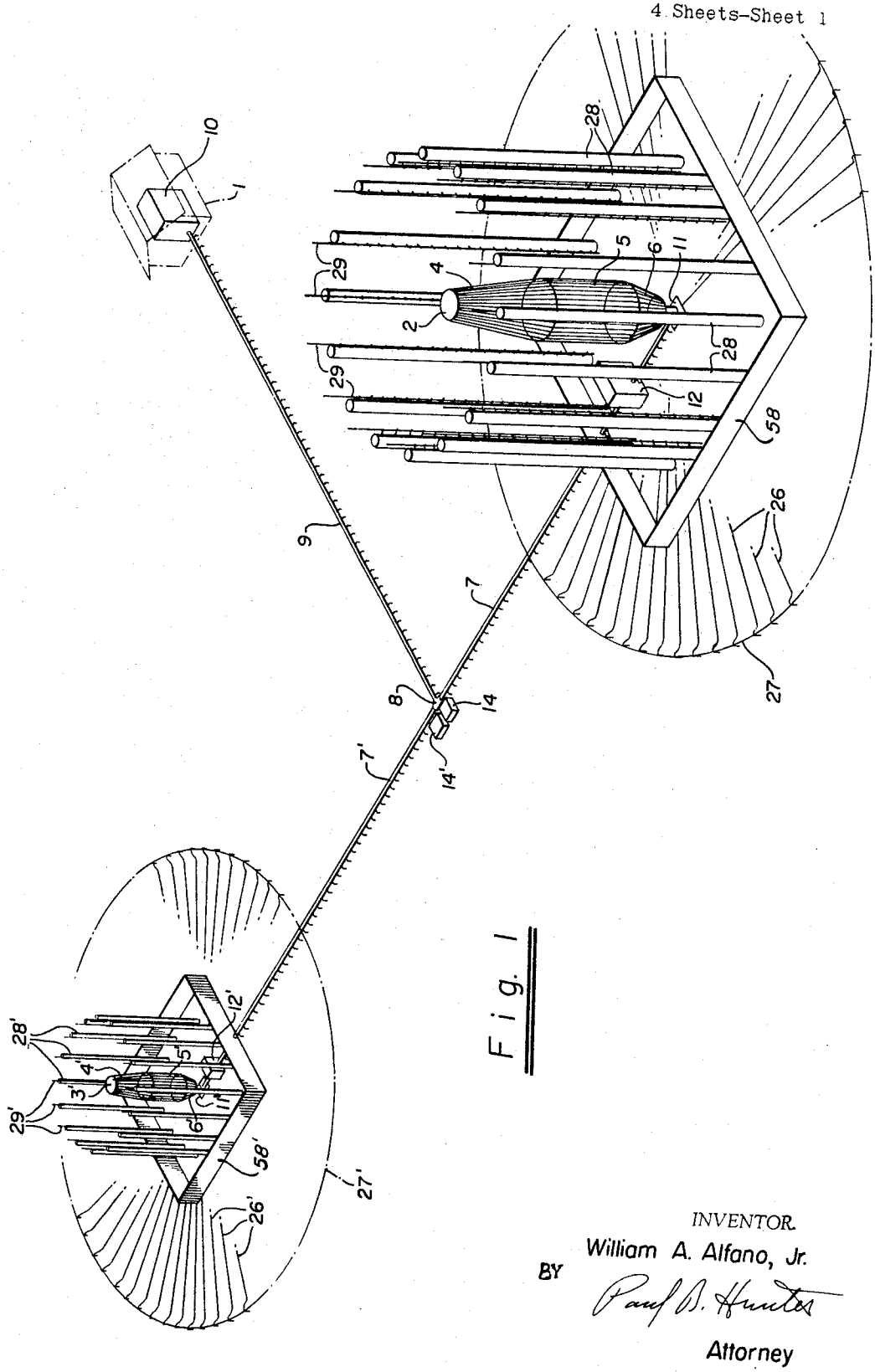


Fig. 1

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4 Sheets-Sheet 2

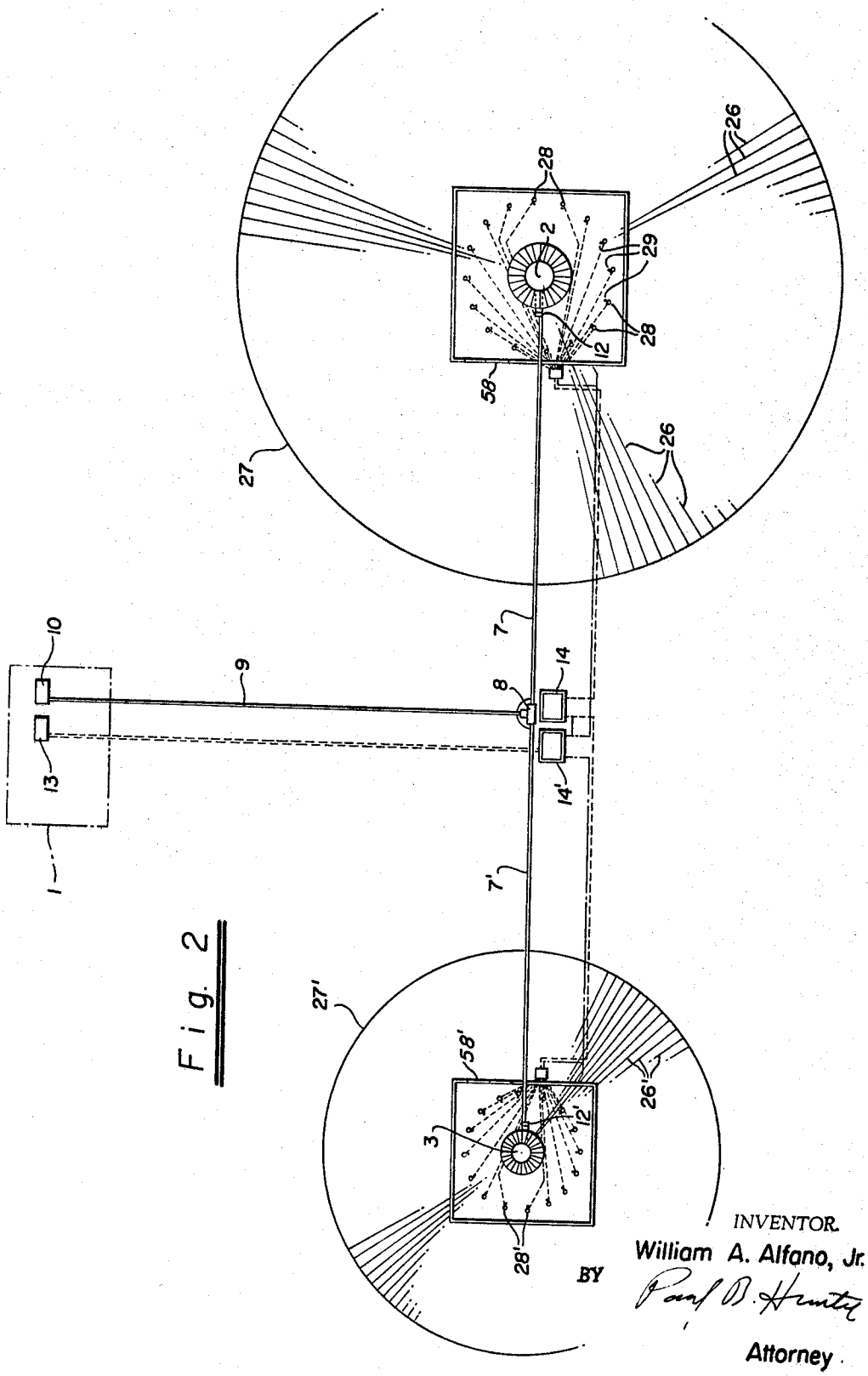


Fig. 2

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4 Sheets-Sheet 3

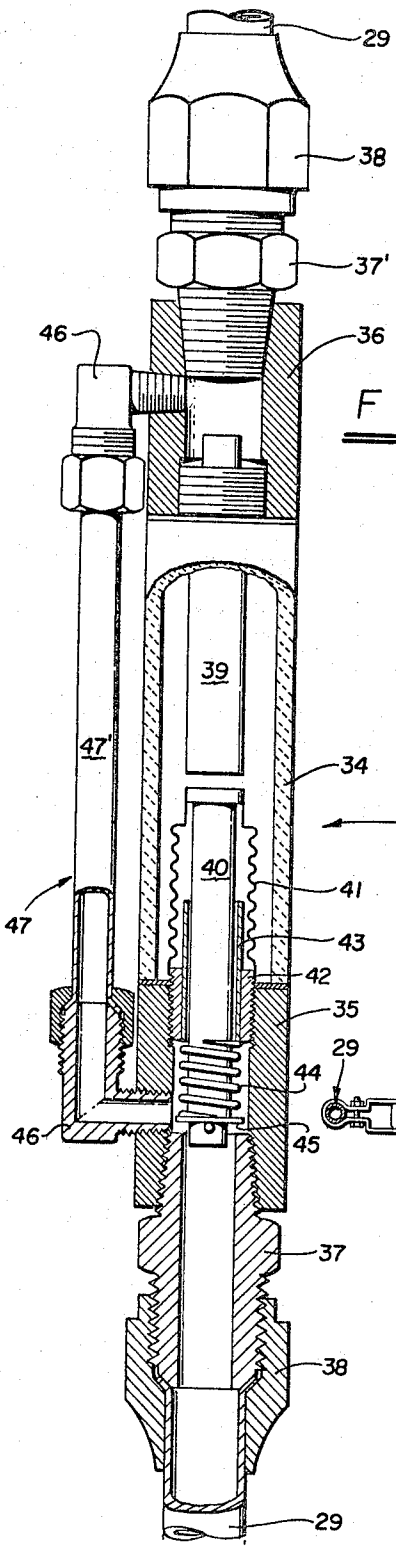


Fig. 4

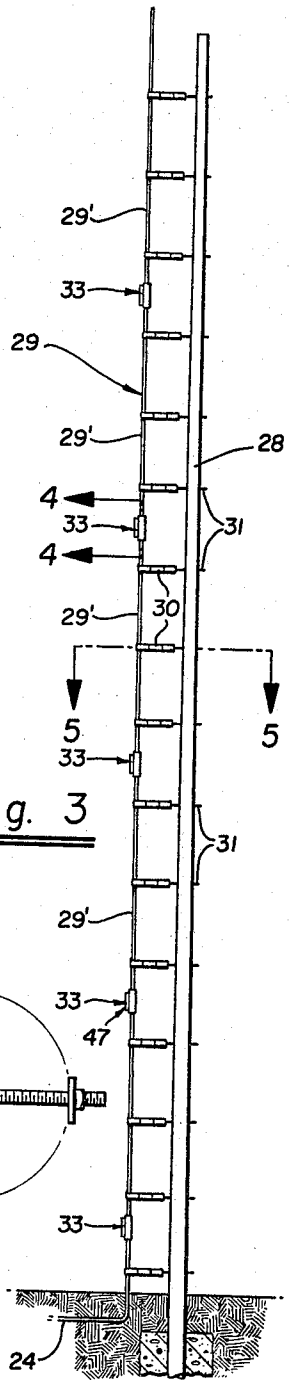


Fig. 3

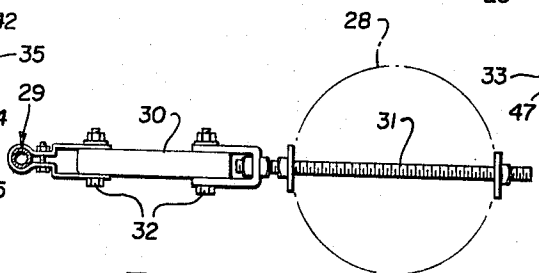


Fig. 5

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4 Sheets-Sheet 4

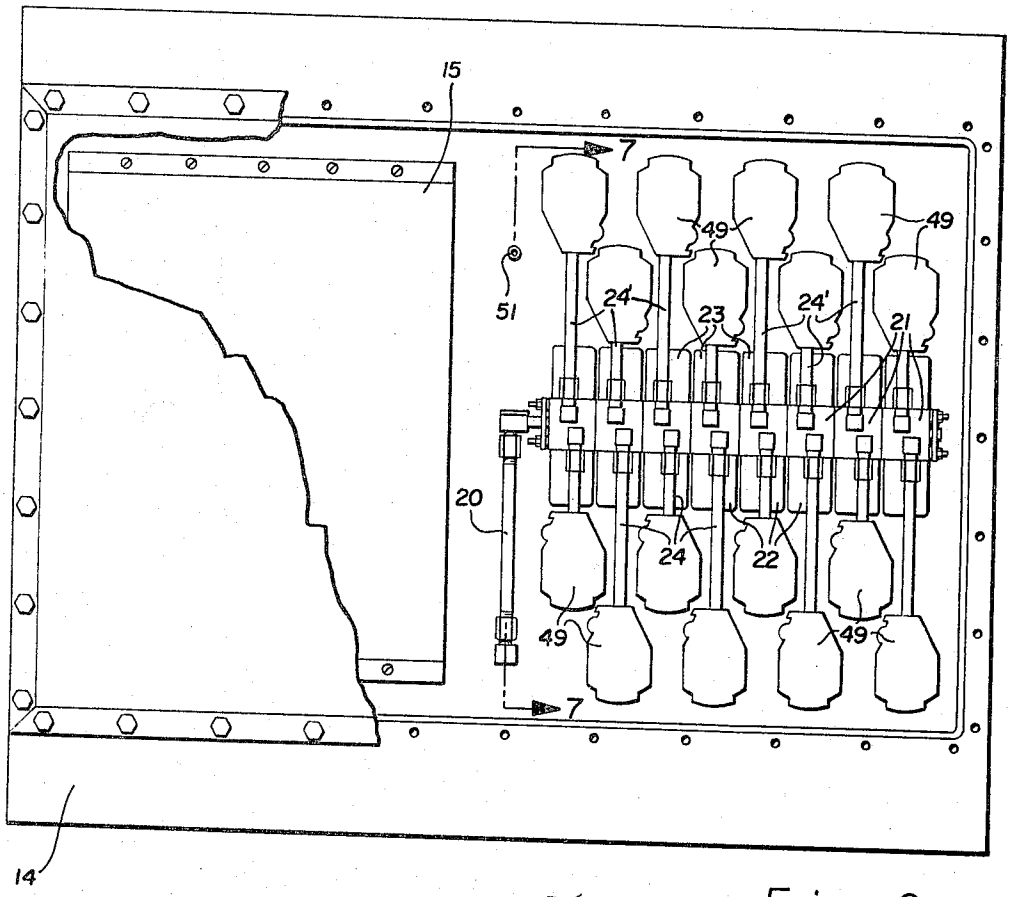


Fig. 6

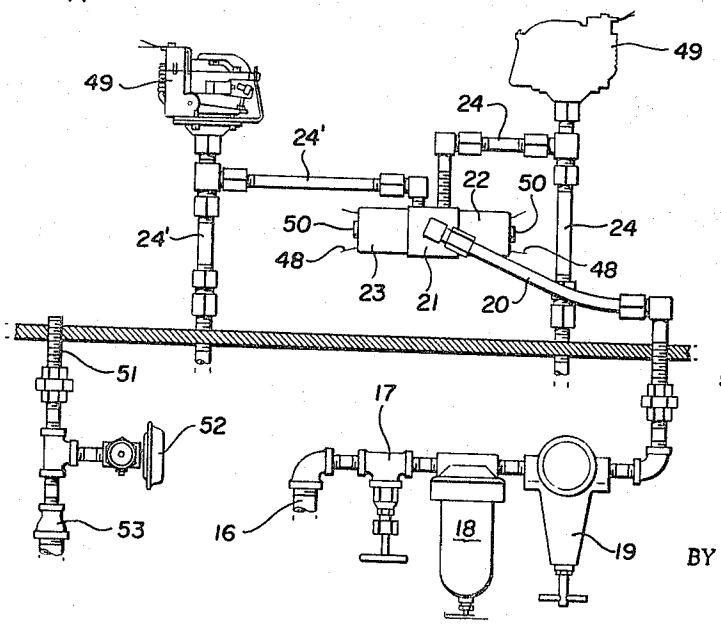


Fig. 7

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STEERABLE MONOPOLE ANTENNA SYSTEM HAVING A PLURALITY OF REFLECTORS, SAID REFLECTORS COMPRISING A SERIES OF TUBULAR VACUUM SWITCHES

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4 Claims. (Cl. 343—836)

ABSTRACT OF THE DISCLOSURE

A steerable, broadband high power antenna system employing a monopole radiator surrounded by circularly disposed mutually spaced reflectors each comprising a plurality of vertically aligned tubular metallic reflector sections having interposed vacuum switches therebetween, said switches having pneumatic by-passes interconnecting successive reflector sections, together with solenoid-operated pneumatic valves selectively controlled to supply compressed air to pre-selected reflectors to actuate desired vacuum switches to closed position and effect changes in the steering and beam width of the radiated energy.

This invention relates generally to steerable antenna systems, and the invention has reference more particularly to a broadband, high power steerable antenna system that is capable of selectively directing electromagnetic beams in a plurality of desired directions, the said beams being variable as to width to encompass variable areas at will.

This application is a continuation-in-part of my patent application Ser. No. 255,920 for "Steerable Reflector Antenna System," filed Feb. 4, 1963, now abandoned.

Heretofore, where it has been desired to obtain a steerable or angularly adjustable or movable radiation transmitting or receiving pattern, it has generally been necessary to use a physically movable structure that is complicated and expensive and ofttimes subject to large wind loadings and having either radio frequency switching or coaxial rotary joints. Furthermore, these sweeping or steerable structures heretofore used generally are limited as to frequency range, whereas the antenna system of the present invention is so designed as to be employed for relatively wide-band use. Attempts have been made to employ directors and reflectors in combination to direct radio beams in a plurality of directions by using a combination of reflectors and directors, but such devices are extremely narrow band and not suitable for present-day needs. Also, these earlier devices encounter difficulty in attempting to broadband the same because of difficulty in switching from director to reflector structures or from reflector to reflector structures.

It is therefore the principal object of the present invention to provide a novel steerable antenna system employing preferably two broadband monopole radiators, one operating over a range of the order of four to eleven megacycles per second and the other operating over a range of the order of eleven to thirty megacycles per second, said antenna system employing a plurality of novel reflectors surrounding each monopole in a circular pattern, said reflectors comprising tubular members capable of being electrically broken as to length through use of novel switching means constituting a part of the tubular members structurally and actuated by pneumatic pressure.

A feature of the present invention is to provide a novel steerable antenna system of the above character wherein the number of effective reflectors surrounding the antennae is selected from a transmitting station through operation of solenoid valves controlling the flow of air to the tubular reflectors and effecting selective operation of the latter.

Another feature of the present invention is to provide a novel steerable antenna system of the above character wherein means is provided for eliminating moisture from the air supplied to the reflector switching means and for discharging air from the hollow reflectors into the concentric feed line of the antenna, thereby maintaining the feed line also free of moisture.

Another feature of the present invention is to provide a novel steerable antenna system of the above character wherein interlocking means is provided for preventing energization of an antenna prior to desired operation of the reflector switches, thereby preventing possible injury to the system.

These and other features and advantages of the present invention will be more apparent after a perusal of the following specification taken in connection with the accompanying drawings wherein:

FIG. 1 is a perspective view of the novel steerable antenna system of this invention;

FIG. 2 is a plan view of a portion of the structure shown in FIG. 1 and illustrates the manner of supplying pneumatic operating pressure to the various antenna reflectors for actuating the switching means and the manner of supplying electrical energy to the antennae themselves;

FIG. 3 is a view in elevation showing a reflector together with its supporting structure;

FIG. 4 is a fragmentary enlarged view of a portion of FIG. 3 encompassed by arrows **4—4**;

FIG. 5 is an enlarged sectional view taken along the line **5—5** of FIG. 3;

FIG. 6 is a plan view with parts broken away showing equipment including a series of solenoid valves for controlling the operation of the reflector switches; and

FIG. 7 is an enlarged fragmentary view taken along the line **7—7** of FIG. 6.

Similar characters of reference are used in the above figures to designate corresponding parts.

Referring now to the drawings, the reference numeral **1** designates a transmitter building shown remote from two monopole radiators **2** and **3** which are also spaced a suitable distance from each other. The monopole **2** having a height of the order of fifty feet is of larger physical proportions than monopole **3** having a height of the order of twenty feet and is a broadband antenna operating over a lower frequency range preferably of the order of four to eleven megacycles per second, whereas the monopole **3** is intended to operate over a higher range preferably of the order of eleven to thirty megacycles per second. The monopole antennae **2** and **3** are shown consisting of upper frusto-conical sections **4** and **4'**, middle sections **5** and **5'** of generally cylindrical shape, and lower sections **6** and **6'** of inverted frusto-conical shape, these sections consisting of a plurality of mutually spaced antenna wires suitably supported by spreader rings to give the desired configuration and providing omnidirectional radiation characteristics, the lower ends of the wires of monopole radiator **2** being electrically connected to the inner conductor of a concentric feed line **7**, whereas the lower ends of the wires of the monopole radiator **3** are electrically connected to the inner conductor of a concentric feed line **7'**.

The outer sheaths or conductors of concentric lines **7** and **7'** are electrically connected to conducting base plates **11**, **11'** that are insulated from the antennae **2** and **3**. Ground screens **26**, **26'** are provided for antennae **2** and **3** and consist of radiating wires welded to plates **11** and

11' at their inner ends and bonded at their outer ends to circular ground wires 27, 27' that are grounded at intervals into the earth. Fences 58, 58' surround the antennae 2 and 3 to protect personnel against injury due to high antenna voltages. The concentric lines 7 and 7' are interconnected intermediate antennae 2 and 3 by a coaxial switch 8 which is adapted to connect either of these branch lines selectively to a main supply coaxial line 9 extending into transmitter building 1 for connection to the transmitter 10 whereby either of the monopole radiators 2 or 3 may be selectively energized from the transmitter 10. The selected monopole 2 or 3 is tuned to the frequency to be transmitted by means of adjustable impedance matching units 12 and 12' located adjacent the respective antennae, which units consist of inductors and capacitors which are shunted across the concentric feed lines 7 and 7' at discreet points as required by vacuum switches controlled from push-buttons mounted on a control panel 13 contained within the transmitter building 1.

A pair of equipment housings 14 and 14' is located substantially midway between antennae 2 and 3 and as shown in FIG. 6 each housing 14 and 14' contains therewithin an enclosed compressor, dehydrator and tank unit 15 which is connected to supply dehydrated compressed air through a pipe 16 (see also FIG. 7), valve 17, filter 18, gauge 19, and pipe 20, to the input of a series of dual solenoid-operated valves 21 connected in tandem. The dual solenoid-operated valves 21 have similar valve portions 22 and 23 on their opposite ends. Valve portions 22 are connected for opening and closing ports leading to a series of pipes 24, eight such pipes being illustrated in FIG. 6 of the drawings, and similarly, the solenoid-operated valve portions 23 are connected for opening and closing ports leading to a series of pipes 24', eight such pipes also being illustrated in FIG. 6 of the drawings.

It will be noted that within each of the housings 14 and 14' there are sixteen of these pipes 24 and 24' when combined, which pipes in the case of housing 14 extend underground and to the vicinity of the monopole radiator 2. As seen in FIG. 2, these pipes are so arranged as to extend respectively adjacent to a series of vertical, preferably wooden, poles 28 disposed in a circle around the antenna 2 and mutually spaced with respect to each other, sixteen such poles being used in the drawings and illustrated in detail in FIGS. 3 to 5. The pipes 24 adjacent the poles 28 are connected to vertically extending hollow reflectors 29 consisting of copper tubes or tube sections 29' which are supported from the poles 28 by means of insulating brackets 30 having threaded stub shafts 31 extending through apertures in the poles 28 and secured thereto as by nuts. The brackets 30 have pivotal bolt connections at 32 to permit thermal expansion and contraction of the hollow reflectors 29 in use by allowing these brackets 30 to swing up and down with respect to the pivotal points. The plurality of aligned tube sections 29' constituting a reflector 29 are interconnected by tubular high vacuum switches 33, five such switches evenly spaced along the reflector being shown for breaking the reflector into short sections which are too short to act as reflectors throughout the frequency band of the antenna. However, when the vacuum switches 33 are closed (as will further appear), all the sections 29' of the tubing are interconnected electrically so that these sections act jointly as a reflector, serving to reflect energy away from the supporting pole 28.

The vacuum switches 33 are shown in detail in FIG. 4, these switches comprising a glazed ceramic, hollow, cylindrical housing 34 sealed at its ends to conducting tubes 35 and 36 as of copper, which tubes in turn are connected as by threaded nipples 37 and ferrules 38 to the copper tube sections 29'. The tube 36 carries a solid, cylindrical contact element 39 sealed therein which element projects downwardly into the housing 34 for cooperating with a similar contact element 40 that has its upper end portion sealed to and supported upon the upper end of a tubular, corrugated bellows 41 having its lower end sealed upon a threaded sleeve 42 that is threaded into the interior of tube 35. The cylindrical contact element 40 has a loose fitting within a sleeve 43 that is fixedly carried by the sleeve 42. A coil spring 44 surrounds the lower portion of contact element 40 and abuts at its upper end against the sleeve 42 and at its lower end against a washer 45 retained on contact element 40 as by a pin. The bellows 41 permits upward movement of contact element 40 into contact with cooperating element 39 when pneumatic pressure is supplied within the bellows, as will further appear; however, in the absence of proper pneumatic pressure, the spring 44 urges the contact element 40 downwardly and out of engagement with the contact element 39 as shown in FIG. 4.

It will be noted that, since pipes 24 and 24' are connected to the vertically extending reflectors 29, air under pressure supplied from compressor, dehydrator and tank unit 15 through solenoid valves 21 and pipes 24 or 24', as will further appear, will flow upwardly within the lowest reflector section 29' and hence upwardly between the lowest contact element 40 and sleeve 43 to effect closure of the first vacuum switch 33. Each vacuum switch is provided with a by-pass 47 comprising elbow fittings 46 threaded into the tubes 35 and 36, the said elbow fittings being interconnected by insulating tubes 47' as of Teflon. Thus, when air under pressure is supplied to the lowest section 29' not only does it serve to actuate the lowest vacuum switch 33 but such air will pass through the by-pass 47 on up to the remaining vacuum switches 33 in succession to thereby electrically interconnect to tube sections 29' of the reflector, rendering this reflector 29 electrically continuous.

Similarly, the compressor, dehydrator and tank unit of housing 14' serves to supply dehydrated compressed air to solenoid-operated valves 21 just as in the case of housing 14, which valves are connected through corresponding pipes 24 and 24' to reflectors 29' supported by poles 28' located in surrounding relation to the monopole radiator 3. The pipes of the compressor, dehydrator, and tank units of housings 14 and 14' are preferably interconnected so that in the case of failure of one such unit the other will take over the load in supplying air to the solenoid-operated valves 21.

Thus, each monopole radiator 2 or 3 is surrounded by a set of sixteen vertical controllable reflectors which are equally spaced around a circle of proper diameter. By actuating all of the reflectors on one side of the circle around the monopole 2 for example, a reflecting screen is formed that concentrates the energy applied to the monopole into a directive beam. By actuating a smaller number of reflectors on one side of the circle, the beam is widened to the point where it provides effective coverage over a larger area. Since the position of the group of active reflectors can be chosen at will from control panel 13 by selectively energizing the valve portions 22 and 23 of the dual solenoid valves 21 through leads 48 (FIG. 7), either of these types of beams could be steered at will to any of sixteen positions around the housing. However, generally, the beam widths involved are such that eight discreet beam positions give adequate coverage at any given direction, so that the system of the present invention provides beam steerage to any of eight equally spaced azimuthal directions. Finally, by deactivating all of the reflectors 29, normal omni-directional coverage is obtained. Therefore, the system of the present invention provides seventeen different coverage modes in the azimuth plane—an omni-directional mode, eight wide coverage modes, and eight narrow coverage modes.

It will be seen that, when the valve portions 22 and/or 23 are energized, compressed dry air supplied from the compressor, dehydrator and tank unit 15 will flow through pipe 16, through filter 18 and pipe 20, to the series of

solenoid-operated valves 21, so that the energized valve portions 22 and 23 will operate to allow such compressed air to enter pipes 24 and 24' as the case may be and flow to the selected reflectors 29 at the desired poles 28. Pneumatic, electrical interlocks 49 are shown connected to the pipes 24 and 24' and each in turn is connected to the control panel 13 for preventing the supply of electrical energy to the desired antenna 2 or 3 until the air pressure within pipes 24 and 24' is sufficient to ensure the operation of the vacuum switches 33 on the poles 28. Normally, the interlocks 49 are set to operate at 35# p.s.i. although the vacuum switches are capable of operating at as low a pressure as 20# p.s.i. When it is desired to deactivate a reflector or reflectors 29, the proper button is pressed at the control panel 13 which serves to de-energize the desired solenoid-operated valve portions 22 and 23 and this in turn allows the compressed air in the pipes 24 and 24' to escape through ports 50 in these valve portions so that springs 44 of the affected switches 33 serve to open the latter, which escaping air maintains the pressure in the housing 14, or 14' as the case may be, at around 5# p.s.i. This air it will be noted is clean and dehydrated, having passed through a dehydrator and a filter, and is discharged through a pipe 51 having a branch with a relief valve 52 therein into a pipe 53 connected to the coaxial lines 7, 7', 9, thereby maintaining these coaxial lines at a slight pressure to exclude external air and maintain clean conditions therewithin, any excess pressure escaping through relief valve 52. Pipe 9 may also have a relief valve within the transmitter building 1 and may even be supplied with dehydrated air at that point should the same prove desirable.

It will be noted that the tubular pneumatic operated reflectors 29 are of extremely rugged and simple construction, the only moving parts being the vacuum switch contacts 40 and the bellows 41 which seals these contacts within the high vacuum of the switches. This construction eliminates switch outer housings and the complexities of supplying mechanical motion to each switch. Installation and maintenance are simplified in that no critical alignment is required and the entire reflector consists of only two modular units, the switch module and the reflector tube.

Tests have shown that the novel antenna system of this invention has an overall band width of from four to thirty megacycles per second and the capacity to transmit 300 kw. average power with instantaneous peaks of 1,200 kw.

Since many changes could be made in the above construction of the novel steerable antenna system of this invention and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A steerable antenna system comprising a vertical monopole antenna, a concentric line connected for energizing said antenna, a plurality of mutually spaced poles surrounding said antenna, tubular reflectors carried by said poles, said reflectors having a series of tubular vacuum switches connected at regular intervals therein and structurally forming portions of said reflectors, said vacuum switches having pneumatic by-passes for passing air therearound, pipes connected respectively to said reflectors, a source of compressed air, solenoid-operated valves connected to said source for selectively connecting the same to said pipes, and control means for selectively energizing said solenoid-operated valves to effect the operation thereof to supply compressed air through said connected pipes to the desired reflectors, said compressed air in passing through said reflectors and through said vacuum switch by-passes serving to actuate said vacuum switches in succession to render said reflectors effective to direct radiant energy from said monopole antenna in a desired direction.

2. A steerable antenna system as defined in claim 1 wherein a second vertical monopole antenna is positioned adjacent said first-named antenna, a main supply concentric line, a second concentric line connected for energizing said second antenna, said second antenna having a frequency band differing from that of said first-named antenna, coaxial switching means for connecting said main supply concentric line to said first and second concentric lines for selectively energizing said antennae, said second-named antenna also having a series of mutually spaced poles arranged therearound, tubular reflectors carried by said poles, vacuum switches incorporated at regular intervals in said reflectors, said vacuum switches having pneumatic by-passes for passing air therearound, additional pipes connected to said latter tubular reflectors, and additional solenoid operated valves connected to said additional pipes, said control means acting to selectively energize said additional solenoid operated valves for selectively energizing said vacuum switches of said second-named antenna reflectors, said antennae being provided with ground screens comprising a plurality of angularly spaced conductors radiating therefrom and connected to ground, said first and second concentric lines having one of their sides connected to a respective ground screen and the other of their sides connected to a respective antenna.

3. A steerable antenna system as defined in claim 2 comprising a sealed housing positioned intermediate said antennae and containing a compressor as said source of compressed air and also containing said solenoid operated valves, a dehydrator interposed between said compressor and said valves whereby only dry air is supplied to said valves and from thence through said pipes to said tubular reflectors thereby preventing corrosion therewithin, and piping connecting the interior of said housing to said coaxial lines, air exhaused by said valves from the pipes leading to said reflectors when the latter are de-energized serving to maintain a desired low internal dry air pressure in said housing and in the connecting concentric lines.

4. A steerable antenna system comprising a transmitter, a control panel adjacent said transmitter, a concentric line fed from said transmitter and having two branches, a pair of remote mutually spaced monopole radiators fed respectively from said concentric line branches, said radiators having differing physical dimensions so together they cover a wide frequency range, a plurality of mutually spaced poles surrounding each of said antennae, tubular reflectors carried by said poles, said reflectors having a series of tubular vacuum switches connected at regular intervals therein and structurally forming a part of said reflectors, a housing intermediate said antennae, a compressor, dehydrator and solenoid actuated valves within said housing and connected to be controlled from said control panel, pipes connecting said solenoid actuated valves to said respective tubular reflectors, whereby said solenoid actuated valves may be selectively controlled from said control panel to activate desired reflectors to direct radiant energy from said antennae in desired directions, and pressure responsive interlock switches connected to said pipes for preventing the energization of said antennae in the event the air pressure within said pipes is insufficient to properly operate said vacuum switches.

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