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Majkrzak et al.

[11] **3,818,488**

[45] **June 18, 1974**

[54] **SHIPBOARD YARDARM HALF-WAVE ANTENNA**

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[51] **Int. Cl.** **H01q 9/16**

[58] **Field of Search** 343/823, 895, 709, 792, 343/822, 885

[56] **References Cited**

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[57] **ABSTRACT**

Two frequency-adjustable antennas of the type having a helix and cylinder coaxially arranged end-to-end are themselves arranged inversely end-to-end in a ½-wave dipole antenna arrangement that is entirely ground plane independent. The end-to-end radiators are arranged about a common drive means which, while providing the main structural support of the antenna arrangement, provides simultaneous synchronous tuning of each leg of the antenna arrangement.

13 Claims, 6 Drawing Figures

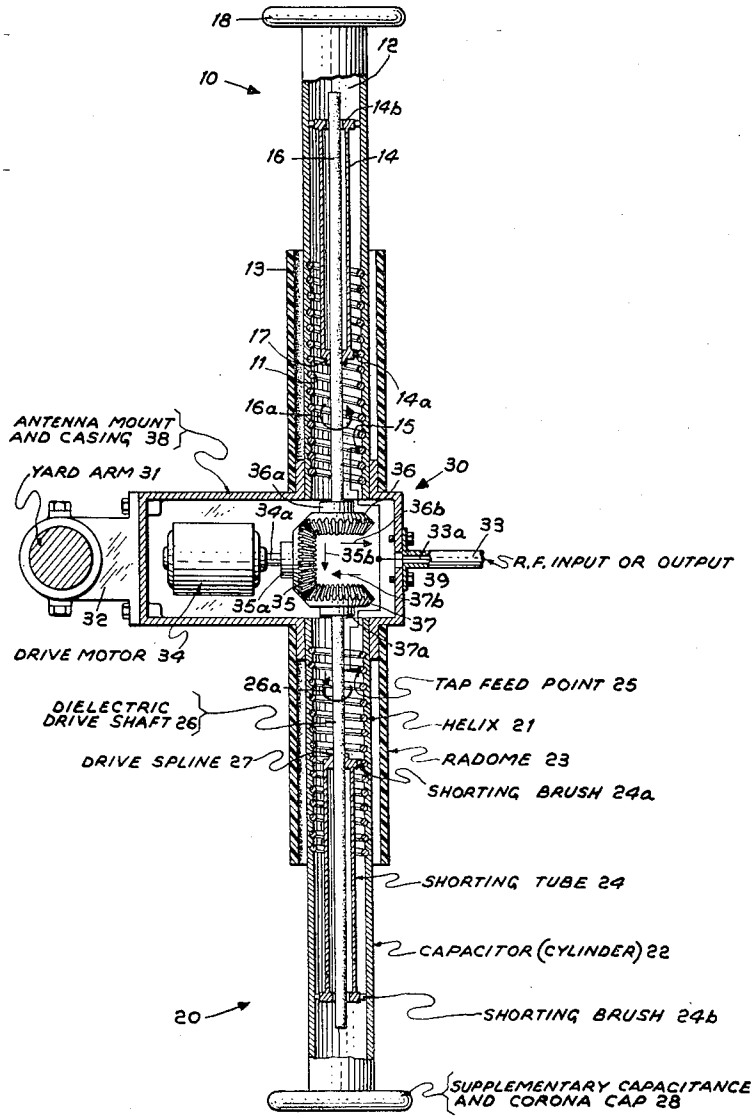


Fig. 1A
(PRIOR ART)

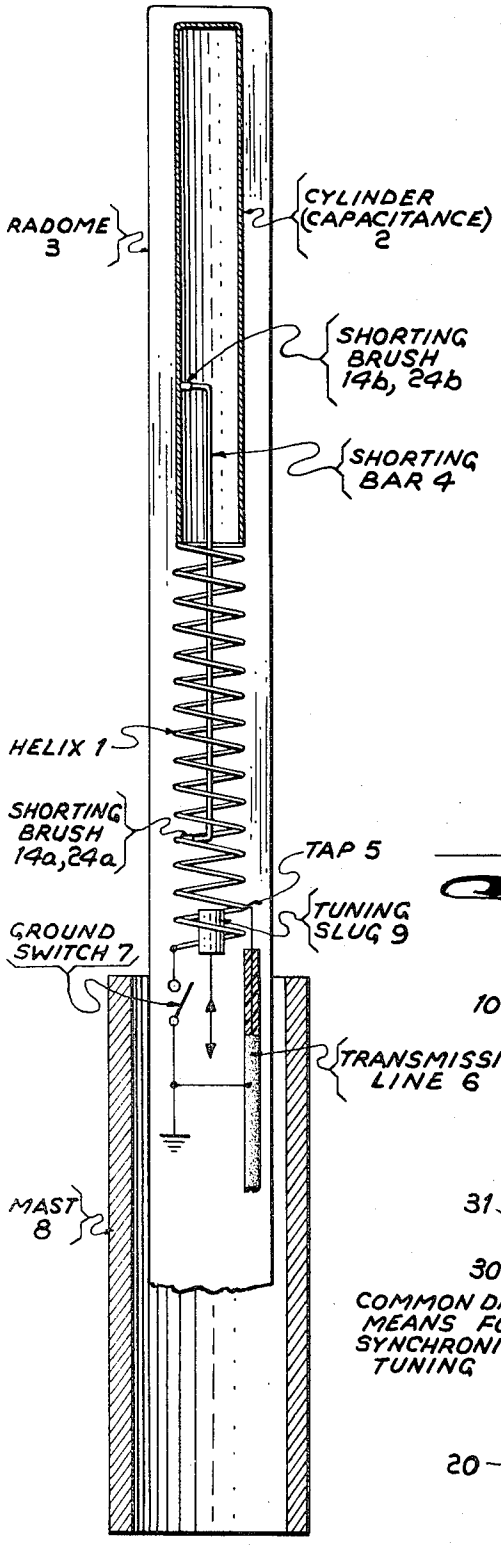


Fig. 1B

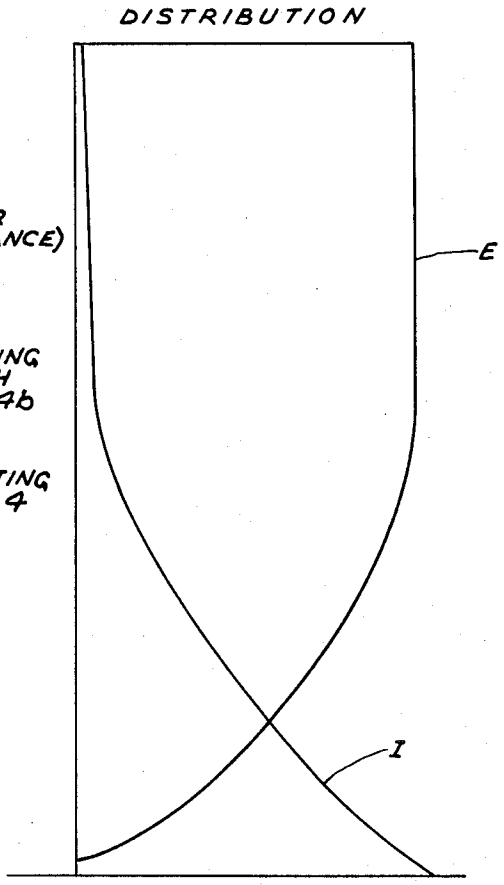


Fig. 2A

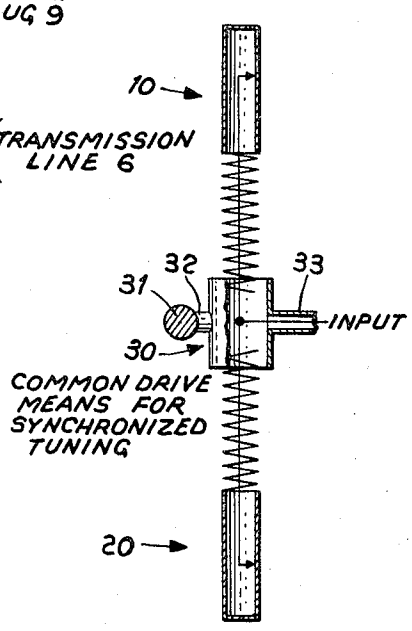


Fig. 2B

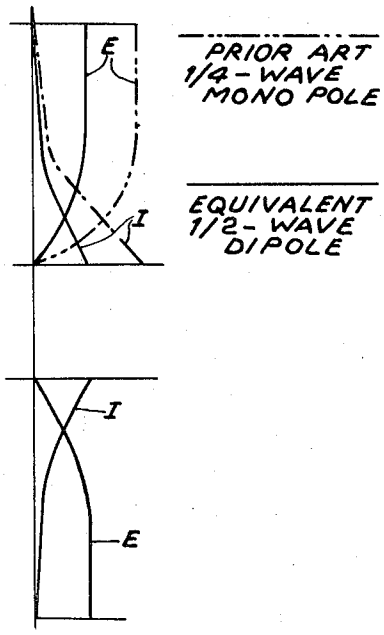


Fig. 3

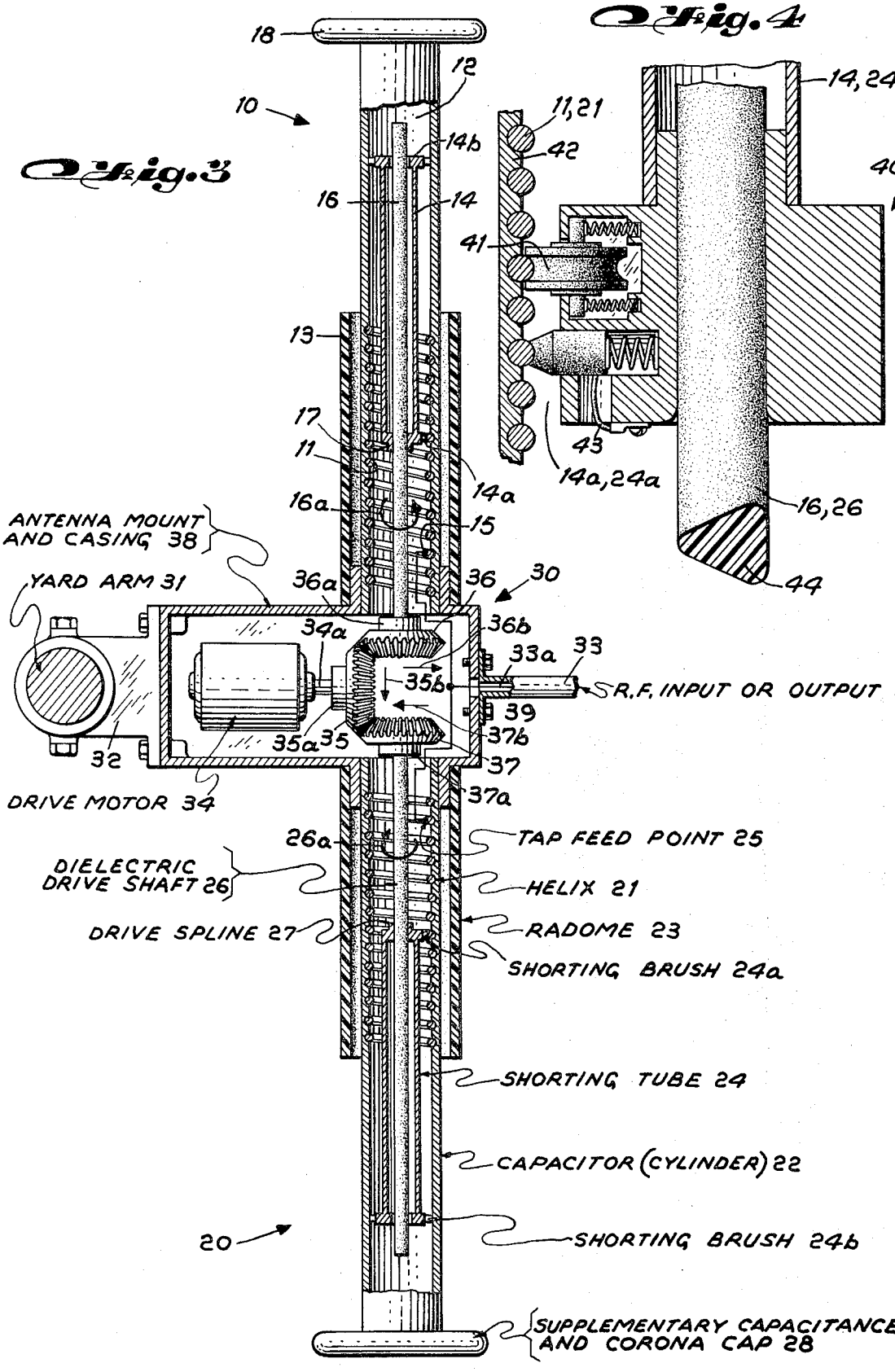

18
12
10
14b
16
14
13
17
11
14a
16a
15
ANTENNA MOUNT AND CASING 38
YARD ARM 31
36a
36
30
34a
36b
33a
33
35b
R.F. INPUT OR OUTPUT
39
32
35a
35
37b
37
DRIVE MOTOR 34
37a
26a
TAP FEED POINT 25
DIELECTRIC DRIVE SHAFT 26
HELIX 21
DRIVE SPLINE 27
RADOME 23
SHORTING BRUSH 24a
SHORTING TUBE 24
CAPACITOR (CYLINDER) 22
20
SHORTING BRUSH 24b
SUPPLEMENTARY CAPACITANCE AND CORONA CAP 28

Fig. 4

14,24
11,21
42
40
41
43
14a,24a
16,26
44

SHIPBOARD YARDARM HALF-WAVE ANTENNA

BACKGROUND OF THE INVENTION

This invention relates to antennas and more particularly to a tunable dipole antenna arrangement having an effective electrical length which may be adjusted to equal desired fractions of wavelengths over a relatively broad band of frequencies.

A related prior art disclosure may be found in U.S. Pat. No. 2,875,433, issued to A. G. Kandoian, Feb. 24, 1959, the subject matter of which, insofar as it is relevant and material to the instant disclosure, is incorporated herein by reference. This prior art antenna arrangement, which may now be identified in the art as a helix/cylinder combination, is an MF/HF antenna optimized for submarine use. Several different versions have been developed. The basic design approach, however, presents the fundamental advantages of high efficiency, reliability and power handling capability. This is a physically short antenna wherein all tuning and matching is accomplished within itself and within a protective radome.

One means for enhancing efficiency is to increase the electrical length of a radiator by reducing the phase velocity on it. This can be achieved by using a resonant helix in the normal mode as the radiating element, which results in a higher radiation impedance, the elimination of an external tuner, and the operation of transmission lines with low standing wave ratios. Since the helix is an inductor, it is possible to tap a feed line into it s few turns from the lowest turn and match impedances without using additional circuits.

For a given efficiency, a helical radiator permits the use of a shorter length than that necessary for a large and unwieldy whip antenna for example. Such helical antennas are quite short enough to permit enclosure within a radome of a submarine, which radome also provides physical support and can be fully retracted into the sub's sail. These features, together with the low loading moments resulting from a short radiator, provide a significant improvement in shipboard reliability. Moreover, it may be readily used as a receiving antenna.

The enclosed radiator is basically composed of a helix and a cylinder thereabove arranged in such a manner as to permit the combination to be electrically tuned to specific frequencies. Tuning is accomplished through varying the effective inductance of the helix in relation to the capacitance of the cylinder by "shorting out" or electrically eliminating helix turns. Power is fed to the antenna through a tap discretely located so as to produce a desired impedance characteristic of say 50 ohms. With the additional use of a grounding switch, the antenna can be tuned over for example a desired frequency range of 2 to 30 MHz with standing wave ratios of below 3 to 1.

The desired tuning characteristics may therefore be had by remotely selecting the proper position of the shorting element and the proper setting for the grounding switch. The shorting element is driven to a select position by an electric motor and held there; a position that corresponds to the desired operating frequency but is determined for example by a precalibrated digital read-out on the front panel of a control unit.

In surface vessel use, the actual efficiency depends significantly upon the height of the antenna above the deck of the ship. There exist definite problems having the antenna mounted on the deck of the ship in order to achieve a ground plane, the problems including hazardous high voltages and radiation being located within easy reach of personnel, and the fact that valuable deck space is required. Moreover, deck gear and ship's structure also interfere with the antenna radiation and give largely unpredictable results.

There has been a long felt need to remove antennas of this type, i.e., with the electrical, and other advantages above-mentioned, from the deck and mount them for example from a yardarm off the ship's mast and out harms way without sacrificing any of the physical or electrical advantages. Until the instant invention, no successful means or arrangement had been found to accomplish this, even though it has been a recognized military problem for over a decade.

The invention achieves the above objective by electrically and physically combining two of the above-mentioned prior art arrangements, significantly modified, end-to-end, in a vertical orientation, thus removing the need for a ground plane, as the inventive antenna arrangement is thus fully capable of ½-wave dipole operation mountable from a yardarm of the ship's mast.

However, the long-recognized problem alluded to above was not solved merely by the end-to-end mounting of these antennas physically and electrically. In the contemplated type of antenna structure, i.e., helix/cylinder combination, it will be appreciated, in view of the prior art above-referenced, that there is an intercoupling member of predetermined length in electrical degrees relative to the intended frequencies of operation, which member is movable to change the operating resonant frequency of the above-referenced antenna by moving the taps on the inductive (helical) part and the capacitive (cylindrical) part in fixed relationship.

Thus, means are required to enable equal simultaneous tuning of both halves of the end-to-end arrangement according to the invention in order that there will be always the same frequency of operation from both halves. This, of course, requires closely identical construction of the two halves or legs of the dipole and also accurate synchronous tuning. The most efficient and dependable synchronous tuning would be a single drive source operating on a common drive mechanism which synchronously tunes both halves simultaneously through exactly the same displacement.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide an antenna arrangement having substantially all the advantages of the above-mentioned helix/cylinder combination antenna, and that is independent of ground plane considerations and may, therefore, be mounted from a yardarm of a mast of a surface vessel, thus eliminating the drawbacks of deck-mounted antenna arrangements.

It is another object of this invention to provide end-to-end helix/cylinder type antennas electrically and physically coordinated by a common drive synchronous tuning mechanism which simultaneously tunes both halves of the antenna arrangement to the same desired frequency.

According to the broader aspects of this invention, there is provided a ½-wave dipole antenna arrangement comprising a pair of frequency adjustable helix/-

cylinder type antennas arranged end-to-end inversely along a principal axis, and means arranged between said helix/cylinder type radiators for providing simultaneous synchronous tuning thereof to the same desired resonant frequency of operation from a common drive source.

Each radiator includes a like-wound helix arranged to have its longitudinal dimension along the principal axis and its one end proximate the common drive means, and a cylindrical capacitive portion also arranged with its longitudinal dimension along the principal axis and having one end thereof proximate the associated helix. Shorting means of predetermined length are arranged to be movable inside each cylinder and helix pair and to be in continual contact therewith, for changing the resonant frequency of operation in accordance with a corresponding change in position of the shorting means along the principal axis.

A feature of this invention is that with the two legs or halves now employed in a dipole arrangement, twice as much power as heretofore realizable in the referenced prior art may be employed.

Another feature of the invention is the accuracy of the tuning; the tuning resettability being so accurate, in fact, that once the system has been calibrated it is unnecessary to apply RF power to resonate the antenna for tuning purposes. The arrangement may be preset to a desired frequency of operation.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other objects and features of this invention will become better understood with reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1A** is a schematic illustration of the prior art helix/cylinder type arrangement similar to the embodiments disclosed in the above-referenced U.S. patent;

FIG. **1B** is a chart of the current/voltage distribution along the antenna arrangement of FIG. **1A**;

FIG. **2A** is a schematic illustration of end-to-end helix/cylinder type antennas arranged in a ½-wave dipole configuration according to the invention;

FIG. **2B** is a graph of the current/voltage distribution of the antenna arrangement of FIG. **2A**, superimposed over the graphical distribution performance of the arrangement of FIG. **1A**;

FIG. **3** is an enlarged schematic diagram of the arrangement of FIG. **2A** giving additional detail; and

FIG. **4** is an enlarged partial sectional view of a preferred configuration of the spline drive/shorting tube portion of the antenna arrangement according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The antenna arrangement according to the invention is an omnidirectional ½-wave dipole, having an intended power rating of up to 10 KW, and an intended frequency range of 2–30 MHz, with a VSWR rating of less than 3:1. The arrangement comprises end-to-end modified helix/cylinder type antennas similar to that described in the referenced U.S. patent, and that shown in the prior art illustration of FIG. **1A**.

The radiator according to FIG. **1A** essentially comprises a conductive helix **1** and a conductive cylinder **2** arranged so as to permit this combination to be electrically tuned to specific frequencies. Tuning is accomplished through varying the effective inductance of the helix in relation to the capacitance of the cylinder by "shorting out" or electrically eliminating helix turns by way of a movable shorting bar **4** of fixed length. Power is fed to the antenna through a tap **5** discretely positioned or adjusted so as to produce the desired matching impedance with the transmission line **6**. Through the additional use of a grounding switch **7**, the antenna can be tuned, for example, over a frequency range of 2 to 30 MHz with standing wave ratios below 3 to 1. As illustrated, the lower portion of the arrangement in FIG. **1A** is housed, for example, in the mast **8** of a submarine.

The desired tuning characteristics are thus derived by selecting the proper position of the "shorting" element **4** by remote control means, and the proper setting of the grounding switch **7**. More specifically, the "shorting" element **4** is driven or moved to a select position by a controlled electric motor (not shown), and held there. This position corresponds to the desired operating frequency and will have been determined for instance by a precalibrated digital readout on the front panel of a control unit (also not shown).

FIG. **1B** represents the current/voltage distribution along the radiator arrangement of FIG. **1A**. In FIG. **1B**, the abscissa represents magnitude and the ordinate the actual longitudinal displacement along the FIG. **1A** radiator. It is to be noted that the highest voltages are present at the cylindrical portion **2** of the antenna and the highest currents at the impedance matching tap point **5** on the helix **1**. Also the current and voltage reach practically a steady-state situation along the greater length of the cylindrical portion **2** of the antenna.

Using the above-described arrangement, a suitable antenna can be configured to operate in a ¼-and ¾-wave mode both for transmitting and receiving. However, this configuration, especially if it is sized to handle higher power for transmission, lends itself only to deck mounting in shipboard use.

If this circuitry were expanded to comprise the equivalent of two antennas mounted inversely end-to-end, it would become ground independent and could therefore become a yardarm-mounted antenna rather than a deck-mounted antenna. Such an arrangement is illustrated in FIG. **2A**, with its corresponding current/voltage distribution graph given in FIG. **2B**. As is also the case in the arrangement of FIG. **3**, the illustrated configuration in FIG. **2A** is depicted in a vertical orientation.

Two helix/cylinder type antennas **10** and **20** are arranged end-to-end and physically separated by a common drive means **30** for providing synchronous tuning of the poles to the desired operating frequency. The arrangmeent is structurally oriented parallel to a ship's mast (not shown), in being suspended at **32** from a yardarm **31** of that mast, by way of the housing or casing of the common drive means **30**. The signal input to the antenna arrangement is at **33**, shown as a coaxial input.

FIG. **2B** illustrates the current/voltage distribution of each leg or half of the antenna arrangement of FIG. **2A**. The solid lines depict respectively the I/V distribution along the end-to-end inversely arranged radiators, while the dot-dashed lines depict, by comparison, the I/V distribution of the lone radiator of FIG. **1A**. To be particularly noted in the upper portion of FIG. **2B** is the

fact that for the same power applied to both antenna arrangements (FIG. 1A and FIG. 2A), the maximum magnitudes of I and E in one leg of the FIG. 2A arrangement are roughly half that of the FIG. 1A arrangement, while the latter also has associated therewith steeper I and E slopes or gradients, thus illustrating the greater electrical stress on the single helix/cylinder arrangement.

In becoming a ¼-wave dipole, rather than a ¼-wave monopole, the individual antenna elements may become lighter in construction since the power will now be equally shared over two symmetrical configurations and components will operate under generally less electrical stress for the antenna's equivalent power rating.

One common tuning drive, housed within the mounting case, mechanically synchronizes both poles to the required operating frequency.

Since a high powered antenna presents a radiation hazard to personnel, it is highly desirable to remove it from deck level to a remote location. Moreover, the removal of the antenna/tuner combination from the deck to upper mast and superstructure level is also highly desirable since deck space is always at a premium. The proposed inventive ½-wave dipole offers the capability for such yardarm installation for both receiving and transmitting antenna considerations.

FIG. 3 illustrates again the end-to-end arrangement of two helix/cylinder type antennas, indicated generally as **10** and **20,** intercoupled by common drive means **30** arranged therebetween, indicated generally at **30.** RF coaxial input (or output) **33** couples signal energy, through the wall of the antenna mount and casing **38** to a common feed point **39** by way of center conductor **33***a*, at which common feed point the power is essentially equally divided to be fed to tap feed points **15, 25** of the respective helix/cylinder antennas **10, 20.** While not particularly shown other than schematically by way of an arrow, the tap points **15, 25** are adjustable up and down the respective helices **11, 21,** in order to establish the best possible impedance match with the input **33.** It is intended that RF transmission line **33** run along the yardarm **31.** Preferably, taps **15** and **25** are adjustably controlled by a common means, either automatically by remote-control switching or otherwise; and that with the adjustment of one there is provided a simultaneous and equal adjustment of the other. It is well within the scope of this invention, however, that the individual setting of taps **15** and **25** may be by hand and separate. Moreover, provision may be made in conjunction with the discretely-stepped adjustment of switching taps to finely control the impedance match in vernier fashion with the continuous adjustment caused by the motor-driven insertiona and withdrawl of a dielectric tuning slug **9** within the helix turns below the input tap, as shown in FIG. 1A. With the inclusion of the tuning slug element **9,** an improvement in VSWR has been experienced in the order of 2:1.

To the horizontally arranged yardarm **31** of a ship's mast (not shown) is coupled or clamped, by way of member **32,** the antenna mount and casing **38** of the common drive means **30** arranged between the radiating halves of the antenna arrangement. This casing **38** houses a remotely controllable drive motor **34** which reversibly drives a common drive gear **35,** which is mounted to the shaft **34***a* of motor **34** by way of gear backing **35***a*. Common drive gear **35** meshes with identical bevel gears **36** and **37** arranged to be at right angles with common gear **35** as shown, and to be driven in the respective directions illustrated by arrows **36***b*, **37***b* responsive to a rotation of the common gear **35** indicated by arrow **35***b* under the control of motor **34.** Both bevel gears **36, 37** have backings **36***a*, **37***a* by way of which they are mountable to respective dielectric drive shafts **16** and **26.** From the indicated rotation of bevel gears **36** and **37,** dielectric drive shafts **16** and **26** respectively turn in the direction indicated by arrows **16***a* and **17***a*. Such a rotation of shafts **16** and **26** is intended to cause an outward movement (away from the common drive means) of shorting tubes **14, 24** respectively arranged about dielectric shafts **16, 26** and coupled thereto at least at one end by way of drive splines **17, 27.**

This movement may be seen in substantially greater detail from the enlarged illustration in FIG. **4.** Spring-loaded grooved rollers **41,** mounted in the brush and guide hub portion **40** of the shorting tube **14, 24** ride on the helix **11, 21,** the latter being shown mounted in a cylindrical-shaped, helically grooved mandrel **42,** as the shorting tube rotates. This imparts a vertical thrust and movement to the shorting tube **14, 24** as it slides axially along the rotating spline drive shaft **16, 26.** As shown, both the shorting brush **14***a*, **24***a* and the grooved roller **41** are spring-loaded mounted; a conductor **43** leads from the brush **14***a*, **24***a* to the body of the brush and guide portion **40** of the shorting tube **14, 24.** FIG. 4 also shows the spline drive shaft **16, 26** as having a triangular example cross-section, indicated at **44.** The arrangement of course causes the shorting tube **14, 24** and brush and guide hub **40** to rotate via this rotating shaft. At each end of the shorting tubes **14, 24** is a shorting brush **14***a*, **14***b* and **24***a*, **24***b*. Preferably, the drive spline associative to each shorting tube may be part of one of the shorting brushes. With the arrangement of the shafts **16, 26** and the shorting tubes **14, 24** inside the respective helix of each leg or half **10, 20** of the antenna arrangement, there is provided by way of motor **34** simultaneous synchronous variation of the position of the shorting tubes **14, 24** in like amount, thus changing the resonant frequency of operation in each leg **10, 20** equally. This is effected in that the two shorting brushes at each end of the shorting tubes are continuously in contact with the conductive and capacitive elements respectively of the associated helix/cylinder antenna, i.e., the shorting brush **24***a* of shorting tube **24** is, for example, in continual internal contact with the turns of the helix **21** of antenna portion **20,** while the shorting brush **24***b* at the other end of tube **24** is continually in contact with the interior of the capacitive portion or cylinder **22,** the counterpart of which in antenna **10** is cylinder **12.** It is contemplated that since helices **11, 21** and capacitive portions **12, 22** are substantailly circular in cross-section and constant in profile, the faces of brushes **14***a*, **14***b* and **24***a*, **24***b* would readily be formed to provide intimate contact with their associated contact surfaces. It is to be noted that helices **11, 21** may be either left or right hand wound, but they are both to be wound the same way.

The helices **11, 21** are entirely arranged in respective dielectric radome sections **13, 23** with the cylinder capacitive portions **12–22** being arranged at the end of these dielectric radome portions **13–23.** Provision may also be made for further capacitance associative to por-

tions **12** and **22** by way of the addition of supplementary capacitive pieces **18, 28,** which take the form of discs or spherical segments (not shown) mounted to the free end of each cylinder **12, 22** in such a way as to form a corona cap capable of preventing electrical discharge from the capacitive member to space.

In order that simultaneous equal tuning of each half of the antenna arrangement may be effected, the two helices **11** and **21** and the two cylinders **12** and **22** should be constructed as nearly alike as possible. This means ideally that helices **11** and **21** should be of common material and have the same number of turns, the same turn pitch throughout, mounted on common insulating material, and be arranged the same distance from the center of the common drive means **30.** Achievement, however, of near-ideal configuration is not a matter of considerable difficulty in the present state of the art. Likewise, cylinders **12** and **22** should be of common material and have substantially the same physical dimensions and position, yielding closely similar capacitances for a particular setting of shorting tubes **14, 24.**

In the arrangement of FIG. **3,** it may be appreciated that continued rotation of dielectric shafts **16, 26** in the directions indicated by arrows **16***a*, **26***a* will eventually enable the shorting tubes **14** and **24** to reach their outermost extended positions, which corresponds to the lowest frequency of operation of the antenna arrangement. In this setting, none or practically none of the helix turns are "shorted out" or rendered electrically irrelevant. Similarly with the shorting tubes **14, 24** at their respective innermost positions (approaching the tap feed points **15, 25**), there is derived the highest frequency of operation.

In the above there has been described a substantial extension in the antenna art representing a solution of a long-recognized problem. Two frequency adjustable helix/cylinder type antennas have been arranged inversely end-to-end to provide a ½-wave dipole antenna arrangement that is entirely ground plane independent. The end-to-end sections are arranged on a principal axis about a common drive means which, while providing the main structural support of the antenna arrangement, provides common drive synchronous equal tuning of both legs of the antenna arrangement.

While the principles of this invention have been described in connection with specific apparatus, it is to be understood that this description is made only by way of example and not as a limitation to the scope of the invention as set forth in the objects and features thereof and in the accompanying claims.

We claim:

1. A ½-wave dipole antenna arrangement comprising a frequency-adjustable helix/cylinder type antennas arranged end-to-end inversely along a principal axis, and means arranged between said helix/cylinder radiators for providing simultaneous synchronous tuning thereof to the same desired resonant frequency of operation from a common drive source; and wherein each said helix/cylinder radiator includes a like-wound helix arranged to have its longitudinal dimension along said principal axis and one end thereof proximate said common drive means, a cylindrical capacitive portion also arranged with its longitudinal dimension along said principal axis and having one end thereof proximate the other end of the associated helix, and shorting means of predetermined length arranged to be movable inside the associated cylindrical capacitive portion and helix and to be in continual contact therwith, for changing the resonant frequency of operation in accordance with a corresponding change in position of said shorting means along said principal axis.

2. The antenna arrangement according to claim **1** wherein said common drive tuning means includes means for securing the antenna arrangement to a ship's mast structure.

3. The antenna arrangement according to claim **1** wherein said common drive means further includes an antenna mount and casing assembly to which are mounted the end-to-end inversely arranged helix/cylinder radiators.

4. The antenna arrangement according to claim **3** wherein said common drive means further includes, inside said mount and casing assembly, a remotely controllable motor controlling a common drive gear by way of the drive shaft of the former, said common drive gear being in mesh arrangement with a pair of bevel gears arranged to be facing each other and positioned at right angles to said common drive gear, the combined drive motor and gear arrangement providing simultaneous synchronous adjustment of the resonant frequency of each radiator.

5. The antenna arrangement according to claim **4** further comprising a radome portion surrounding the helix of each radiating half of the antenna arrangement, which randome portions each communicate at one end thereof with the mount and casing assembly of said common drive means.

6. The antenna arrangement according to claim **4** wherein said bevel gears are mounted on respective dielectric drive shafts communicating with said adjustable shorting means associated therewith for adjusting the resonant frequency of operation.

7. The antenna arrangement according to claim **6** wherein each said shorting means comprises a metallic shorting tube of substantially right cylindrical shape and having at each end a coaxially mounted disc-shaped shorting brush extension for providing said continual contact respectively with said cylindrical capacitive portion and said helix associated therewith.

8. The antenna arrangement according to claim **7** wherein said dielectric shafts communicate with said respective shorting means by way of at least one drive spline arrangement arranged on said shorting tubes.

9. The antenna arrangement according to claim **8** wherein said drive spline arrangement of each said shorting tube is included as part of one of said disc-shaped shorting brushes.

10. The antenna arrangement according to claim **1** wherein RF signal energy is coupled between the antenna arrangement and an RF transmission line by way of a coaxial connection mounted through a side of the antenna mount and casing assembly of said common drive means, said coaxial connection being electrically coupled to a common feed point whereat the signal energy divides to be fed to each radiating half of the antenna arrangement.

11. The antenna arrangement according to claim **10** wherein the divided signal energy is fed to the respective helix portions of the two radiating halves of the antenna arrangement by way of respective adjustable taps, arranged to be movable along the helix associated therewith in a selection of a particular helix turn to

thereby provide an impedance match with said RF transmission line.

12. The antenna arrangement according to claim **1** surther comprising a pair of disc-shaped supplementary capacitive members mountable on the free end of the respective cylindrical capacitive portions of the two radiating halves of the antenna arrangement, each said member by way of its shape serving also the function of a corona cap for discouraging corona discharge from the associated cylindrical capacitive portion to other structure arranged nearby.

13. The antenna arrangement according to claim **1** further including a dielectric slug tuning means, movably arranged to be inserted in the axially direction into the end of the helix portion of each said helix/cylinder radiator nearest said common tuning means, for finely controlling impedance match of the antenna arrangement in vernier fashion through continuous adjustment capability.

* * * * *