Nov. 17, 1970 E. N. WILLIE ET AL 3,541,555

DIPOLE ANTENNA SYSTEM

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FIG.1.

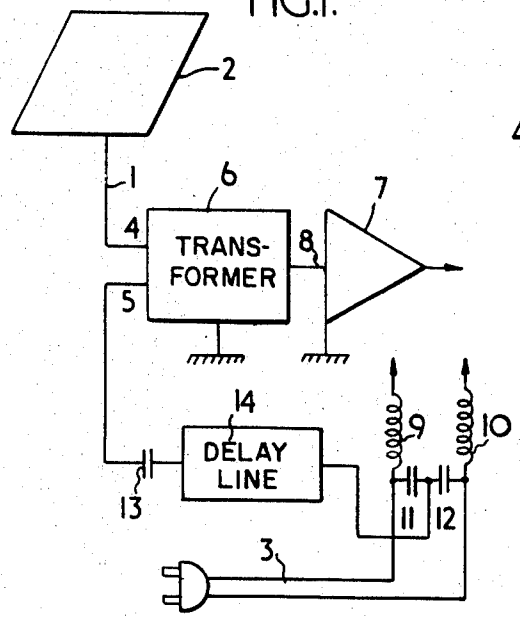


FIG.2.

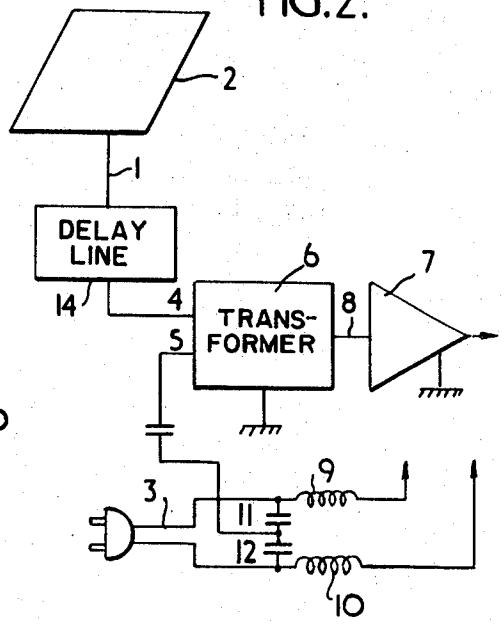


FIG.3.

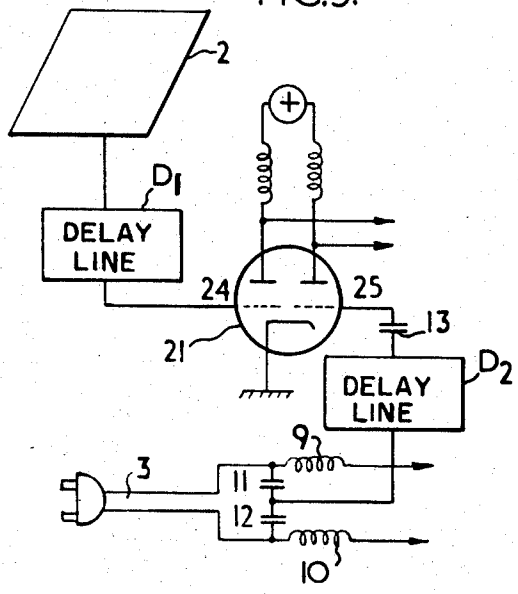


FIG.4.

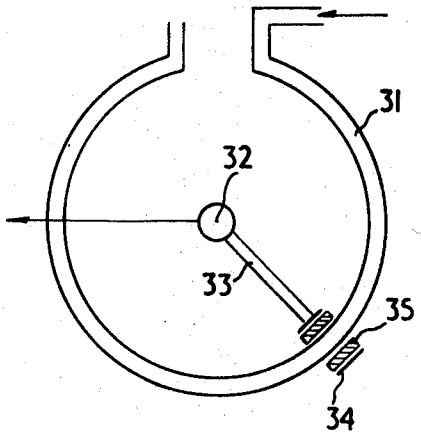


FIG.5.

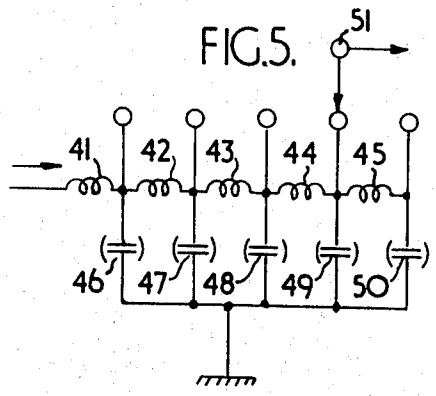


FIG.6.

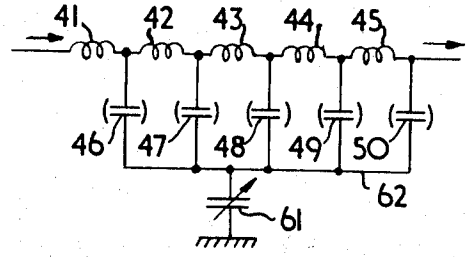


FIG.7.

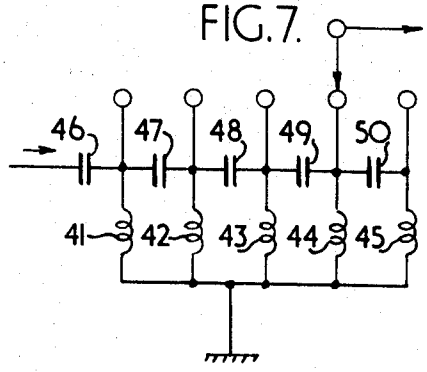
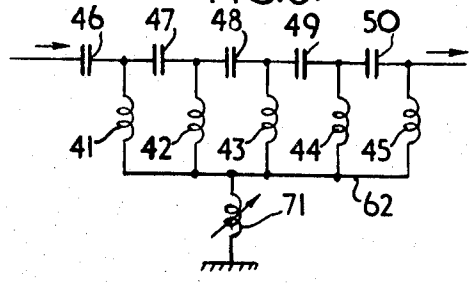


FIG.8.



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FIG.9.

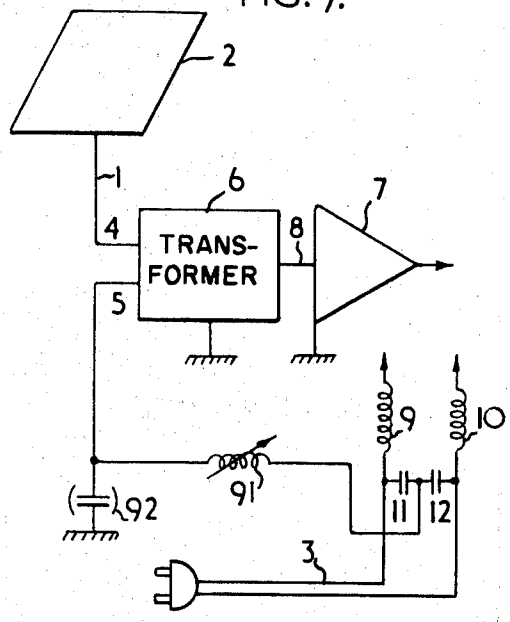


FIG.10.

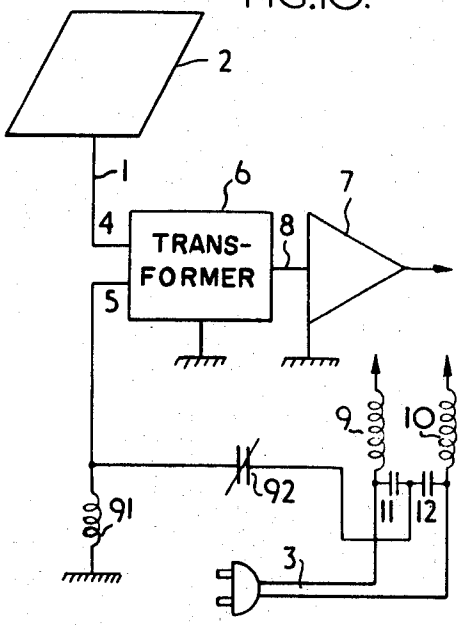
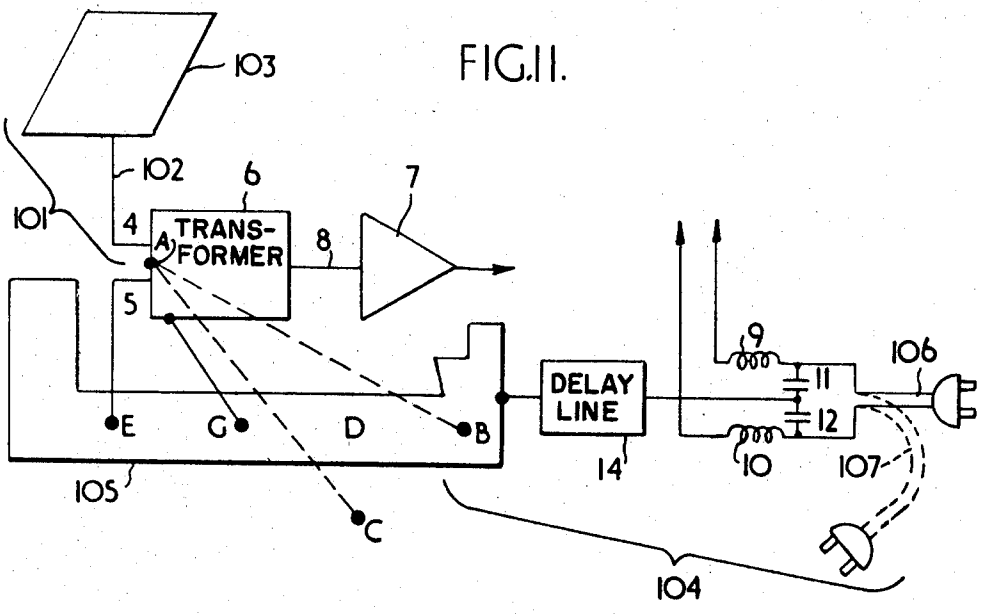


FIG.11.



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DIPOLE ANTENNA SYSTEM

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Int. Cl. H01q 9/16
U.S. Cl. 343—720 7 Claims

ABSTRACT OF THE DISCLOSURE

A dipole antenna system wherein one arm of the dipole is fixed and the other arm may be randomly positioned and/or of random length including a phase adjustment device associated with one or both arms to maintain the signals from the two arms in the desired phase relation.

Dipole antennas, when connected in the customary manner to the differential input terminals of a receiver, are subject to differential phase errors between the dipole's arms. Such errors can, as it is well understood, be caused by incidental reflectors and re-radiators, creating signal delays or advances in one dipole arm with reference to the other; and partial or complete signal cancellations can ensue, even if signal strength at the receiver's location is relatively high.

This familiar reception problem, which is probably best known as the cause of reception difficulties of television receivers with indoor antennas ("rabbit ears"), can be further aggravated if a non-symmetrical dipole is used, especially if one dipole arm is flexible meaning that it can freely move in its direction and length, while the other arm remains essentially fixed.

A good example, which will also be used to illustrate the nature of our invention, is a vertical or horizontal dipole in which one arm is represented by a power cord while the other arm is a stationary monopole, attached to the inside or outside of the receiver. Power cords are flexible and subject to random placement and prone to accidental shifting, and means must therefore be provided for re-establishment of original performance if such accidental shifting has occurred. In addition, a power cord, when used as an antenna, may differ in its length more drastically from the ideal mid-band quarter-wave length of its companion dipole arm, causing the receiver to perform poorly at some freqeuncies only, while it is satisfactory on others.

The present invention eliminates the above-described problem through recognition of the following facts:

(1) If the second, flexible dipole arm does not properly match the effective length of the first, fixed arm, it is less the difference in signal amplitude, due to differing length, which causes intolerable signal losses, than major phase shifts between the movable and the fixed arms' signals. These phase shifts are capable of partially or completely disabling the receiver's differential input circuit by being in less than exact phase-opposition and, in the ultimate case, approaching phase-identity.

(2) Any receiver which is operated with a fixed internal or external indoor aerial requires one control less to be handled, namely, the turning and angular adjustment of a conventional indoor dipole (or monopole) antenna. Its user can therefore be expected to be willing and able to adjust a dummy control, labelled "Aerial," which improves the set's performance in exactly the same manner in which the customary turning and tilting of a conventional indoor antenna would improve performance.

Accordingly, this invention provides such a control; it does, however, not physically rotate, lengthen or shorten the flexible aerial (for instance the power cord). Instead, it corrects mutual phase shifts between the signals taken from the two arms of the dipole.

The invention can assume several practical forms of execution. It will be better understood by referring to the drawings, in which:

FIG. 1 is a schematic diagram of a differential input transformer and vertical dipole antenna, using a power cord and adjustable delay line in place of its customary lower arm,

FIG. 2 is a schematic diagram of a similar antenna system, having the delay line relocated in the dipole's upper arm,

FIG. 3 is a schematic diagram of antenna system having a transformerless, differential input circuit,

FIG. 4 illustrates a stepless delay line with distributed inductances, and

FIGS. 5–8 illustrate various other delay lines with lumped inductances and capacitances, creating either positive or negative delays.

FIGS. 9 and 10 show examples of simplified, single step, delay lines for positive or negative delay, while

FIG. 11 shows the present invention applied to a "semi-flexible, semi-grounded" dipole, one arm of which is subject to phase-randomness while extracting signal energy from space.

Referring to the antenna system shown in FIG. 1, there is shown an essentially fixed vertical monopole **1**, having its effective height increased by a capacitive termination **2**. Monopole **1** together with power cord **3** forms a dipole which, if the power cord hangs straight down from the receiver, is a true, vertical dipole. On the other hand, if the cord **3** leaves the receiver in a horizontal direction, the combination represents an oddly tilted dipole. In either case, the signals delivered to the input terminals **4** and **5** of the differential antenna transformer **6** may or may not be in phase-opposition, as they should be, if the largest possible signal is to be delivered to the input of the RF amplifier **7** through lead **8**.

The power cord **3** is RF-isolated from the set's chassis (not shown) by inductors **9** and **10**, as well as blocking condensers **11**, **12** and **13**. A continuously variable delay line **14** is inserted in series with blocking capacitor **13** and the lower differential transformer input terminal **5**. The control knob or bar (not shown) of variable delay line **14** is accessible from the outside of the set. The control knob may be marked "Aerial" and can be used in exactly the same manner in which an indoor antenna would customarily be rotated for optimum performance.

Assuming, for instance, that the cord **3** hangs vertically, and that its length plus incidental capacitive termination, created by the power outlet, causes it to have an effective antenna height of ¾ wavelength, while a given frequency is received, and that the fixed, capacitively terminated monopole **1** has an effective height of ¼ wavelength, the signals arriving at the differential input terminals **4** and **5** of the antenna transformer **6** would, if any signal delays in the upper and lower antenna leads (including delay line **14**) are identical, be in exact phase-agreement. The transformer's differential characteristics would then cause the two signals to cancel out, unless a phase correction is included to make reception possible.

The reason for phase agreement between leads **4** and **5**, in spite of different effective antenna heights (¼ and ¾ wavelengths) is that the two points of signal-origin face the point of reference, between the transformer input terminals, in opposite directions: the upper signal faces down, the lower up.

If sufficient delay range is provided in the adjustable

delay line **14**, the desired perfect phase-opposition at the transformer's input terminals can always be achieved by adjusting the amount of delay, in accordance with varying frequencies received, varying reflector and re-radiator effects, and cord positions.

The circuit in FIG. 2 is nearly identical with the circuit in FIG. 1. Only the location of the delay line has been altered: in FIG. 1 it is in series with the line-cord antenna, in FIG. 2 in series with the upper, fixed antenna. Corresponding components are identified by identical numbers.

FIG. 3 illustrates the obvious fact that the invention is not restricted to differential antennan transformers. The dual triode **21** shown here has two input grids **24** and **25** which take the place of input terminals **4** and **5** of the differential antenna transformer in FIGS. 1 and 2. Components, corresponding to FIGS. 1 and 2, are identified in FIG. 3 by identical numbers. The adjustable delay line **14** is not shown in FIG. 3, only its alternative locations D_1 or D_2, in the upper or lower aerial leads, respectively.

The delay line itself can assume many forms of which some examples are given in FIGS. 4 through 8.

The delay line shown in FIG. 4 is a sufficiently large wire loop **31** having a signal input at **36**, and having in its center a pivot **32**, from which the output signal is taken. Attached to the pivot **32**, is an arm **33** carrying a metallic cylinder **34**, which is insulated from the wire loop **31** by cylinder **35**, and slides the metallic cylinder **34** along the circumference of the loop, as the pivot **32** is rotated. The signal is capacitatively transferred from the loop **31** to the cylinder **34**, and the desired delay, i.e., the delay which minimizes signal cancellation between the upper and lower sections of the dipole, can be adjusted by rotating the pivoted arm **33** and thereby varying the length of loop included between the signal input **36** and the signal output at the pivot **32**.

The delay line shown in schematic form in FIG. 5 uses lumped inductors **41, 42 . . . 46** and capacities **46, 47 . . . 50**, in conjunction with a selector switch **51**, as means for selection of optimum delay. The capacities can be discrete or incidental (condensers or stray capacities).

The delay line shown in schematic form in FIG. 6 also uses lumped capacitive and inductive reactances, identified by numbers corresponding to those in FIG. 5. However, the capacities or condensers **46, 47 . . . 50** are not grounded directly, as in FIG. 5, but are grounded through an adjustable capacitor **61** which adjusts the delay in the following manner: Adjustable grounding capacitor **61** is appreciably larger than the remaining capacities, and will therefore effectively ground busbar **62** to which all delay line capacities are referred, either by direct connection or through mutual capacity. Busbar **62** can be a wire, a metallic frame, or a near-ground surface etc. In its maximum capacity position, grounding capacitor **61** creates a maximum delay, and in its minimum position, a minimum delay. The latter is true because capacitors **46, 47 . . . 50** act as partial shunts of inductors **42, 43, 44** and **45**, since each pair of adjacent condencers, being series-connected acts as such a shunting capacity.

The delay line of FIG. 7 is similar to that of FIG. 5, except that the location of the delay line inductors and capacitors are reversed. This causes a negative rather than positive delay which, if sufficient delay range is provided, is equally useful for the purpose of proper signal phasing between the upper and lower dipole sections. The components of the delay line of FIG. 7 are designated by the same numbers as the components in FIG. 5.

The delay line of FIG. 8 is similar to that of FIG. 6 with the exception that the locations of the inductors and capacitors are reversed. Busbar **62** is grounded through a variable inductor **71** which, at its minimum inductance position, effectively grounds inductors **41, 42 . . . 45**, causing maximum negative delay, and at its maximum inductance position, causes minimum delay. The individual inductors **41, 42, 43** and **44**, being series connected, act as shunts of the in-line condensers **47, 48, 49** and **50**, causing the negative delay to be a minimum.

FIG. 9 shows a dipole antenna system including a single step L/C-delay line operating near resonance which is a simplification of the lumped reactance delay line of FIG. 5. It sacrifices a minor amount of signal amplitude which, in view of the greater seriousness of signal cancelling phase errors, can usually be tolerated.

A single step L/C-delay line, near resonance, creates only a 3 db amplitude loss between plus/minus 45° phase shift limits, or 90°, if one 3 db extreme is used as the zero delay reference.

As shown in FIG. 9 the single step L/C-delay line is inserted into the lower dipole lead. It consists of adjustable inductor **91** and fixed capacitance **92**. The latter may, as before, be either discrete or incidental. If discrete, it may be made adjustable and inductor **91** can be fixed, or both can be made adjustable, to provide a large phase range without increasing maximum amplitude loss.

FIG. 10 illustrates a dipole antenna system including a single step negative delay line achieved by the reversal of the locations of capacity **92** and inductance **91**, of the delay line of FIG. 9.

The present invention is not limited to the use of a power cord as the second arm of a dipole, the first arm of which is essentially in a fixed position. Other electric cords, metallic stands and metallic furniture, ear phone cords etc. can take the place of the power cord, and their signals brought into proper phase relationship with the dipole's fixed arm. Neither is our invention restricted to vertical dipoles, whether partially capacitively terminated, as shown in the drawings, or not. Horizontal dipoles, having one fixed and one randomly placed arm, fall within the scope of our invention, including the special case of the half-grounded, half-mobile dipole shown in FIG. 11.

The dipole shown in FIG. 11 consists of an upper arm **101**, composed of vertical lead **102** and capacitive termination **103**, which is in an essentially fixed position with reference to point A, the midpoint between the input terminals **4** and **5** of the differential antenna transformer; its other, lower arm **104** consists of two sections **105** and **106**. The first of these sections, **105**, is the chassis, which, is fixed with reference to point A, the other **106** is the power cord which can assume various positions in random fashion. The electrical center of this combination, point B, is subject to random shifts which, are caused by random placement of the combination's mobile part, cord **106**. Thus the electrical vector A–B of the lower arm of the dipole can change its direction and length to a new position A–C, if the cord **106** is shifted to a new position **107**. If wave length, chassis size, cord position and cord length happen to coincide unfavorably, total or nearly total cancellation of the signals in the two transformer input leads **4** and **5** is possible, in spite of the fact that lead **5** is grounded to the chassis and lead **4** is not. This experimentally confirmed problem can best be explained as follows:

(1) It is virtually impossible to ground the input transformer to a point on the chassis which coincides with its electrical center (exclusive of the cord) D in such manner that the ideal ground point A in the transformer, which is its electrical center between its input terminals **4** and **5**, coincides physically with point D. This would have to be a connection without length and without reactive as well as resistive properties, impossible to produce, the more so since the true location of neither A nor D can be pin-pointed.

(2) Even if it could be pin-pointed, it would change with frequency in view of unavoidable imperfections of the transformer and other contingencies.

(3) The chassis to which input lead **5** is "grounded" is, in reality, an aerial which is linked with signals and space, both capacitively and inductively. In the absence of the

ideal ground connection between chassis and antenna transformer a signal voltage can therefore develop between A and the physical "grounding" point E of input lead **5**, and a significant current can flow in this lead, the more so since the radiation resistance of the chassis, due to its bulk, is relatively low.

This undesired capability of the chassis to act as an antenna is greatly enhanced if the power cord is RF grounded to it, as often found in small, transformerless receivers. Even if no intentional grounding is provided, stray capacities are usually sufficient to cause the power cord to be included in the overall contour of the chassis, acting as an antenna. Due to the cord's physical shape its effect upon chassis contour is increased many times beyond the simple volumetric or surface increase. The cord being roughly shaped like a linear antenna is actually capable of "pumping" a substantial amount of signal energy into the chassis, making the "half-grounded dipole" in FIG. 11 respond to random cord placement in almost the same manner in which the floating dipoles in FIGS. 1, 2 and 3 respond, as far as random phase shifts and accidental signal concellations are concerned.

An adjustable positive or negative delay line **14**, in FIG. 11, therefore, can eliminate the signal cancellation problem in a semi-grounded, semi-flexible dipole (whether vertical or horizontal) in the same manner as it solves this problem in floating, semi-flexible dipoles. The delay line can, again, be located either in the signal path of the power cord, as shown, or in the upper antenna lead. It can also be located in lead F–G, physically grounding the differential input to the chassis.

Although the present invention has been illustrated by reference to several preferred embodiments, it will be appreciated by those skilled in the art that the present invention is not limited to such embodiments. It will further be apparent to those skilled in the art that other modifications and adaptations of the apparatus may be made without departing from the spirit and scope of the invention as set forth with particularity in the appended claims.

What is claimed is:

1. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said variable delay line comprising an output conductor, an input conductor disposed about the periphery of a circle, a movable arm pivoted at the center of said circle, a coupling device connected to said output conductor and mounted on said movable arm in sliding engagement with said input conductor for coupling signals from said input conductor to said output conductor.

2. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable phase retarding delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said variable phase retarding delay line comprising a plurality of series connected inductors, a plurality of capacitors connecting the junctions between said inductors to ground, and a selector switch for selective connection to the junctions between said inductors.

3. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable phase retarding delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said variable phase retarding delay line comprising a plurality of series connected inductors and a plurality of capacitors connecting the junctions between said inductors to ground through a relatively larger variable capacitor.

4. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable phase retarding delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said variable phase retarding delay line comprising a variable inductor connected in series between said arm and said differential input signal device, said variable inductor being capacitively connected to ground.

5. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable phase advancing delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said phase advancing delay line comprising a plurality of series connected capacitors, a plurality of inductors connecting the junctions between said capacitors to ground, and a selector switch for selective connection to the junctions between said capacitors.

6. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable phase advancing delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said variable phase advancing delay line comprising a plurality of series connected capacitors and a plurality of inductors connecting the junctions between said capacitors to ground through a relatively large inductor.

7. A dipole antenna system comprising a substantially fixed arm and a flexible arm, a differential signal input device, and a variable phase advancing delay line connected between at least one of said arms and said differential signal input device for maintaining the signals from said arms substantially in phase opposition, said variable phase advancing delay line comprising a variable capacitor connected in series between said arm and said differential signal input device, said variable capacitor being inductively connected to ground.

References Cited

UNITED STATES PATENTS

2,000,529	5/1935	Livingston	343—899 XR
2,562,654	7/1951	Williams	343—720 XR
2,666,846	1/1954	Davis	343—720 XR
2,911,643	11/1959	Gergely	343—906 XR
2,991,355	7/1961	Spindler	343—906 XR

OTHER REFERENCES

"Understanding Amateur Radio," Grammer, The American Radio Relay League, West Hartford, Conn., 1963, TK6550 G7, pages 113–115, 211–213, and 287–289 and title page.

"The Radio Amateur's Handbook," The American Radio Relay League, Inc., West Hartford, Conn., 1946, TK6550 R162, page 250.

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U.S. Cl. X.R.

343—750, 822, 908