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HIGH FREQUENCY ANTENNA

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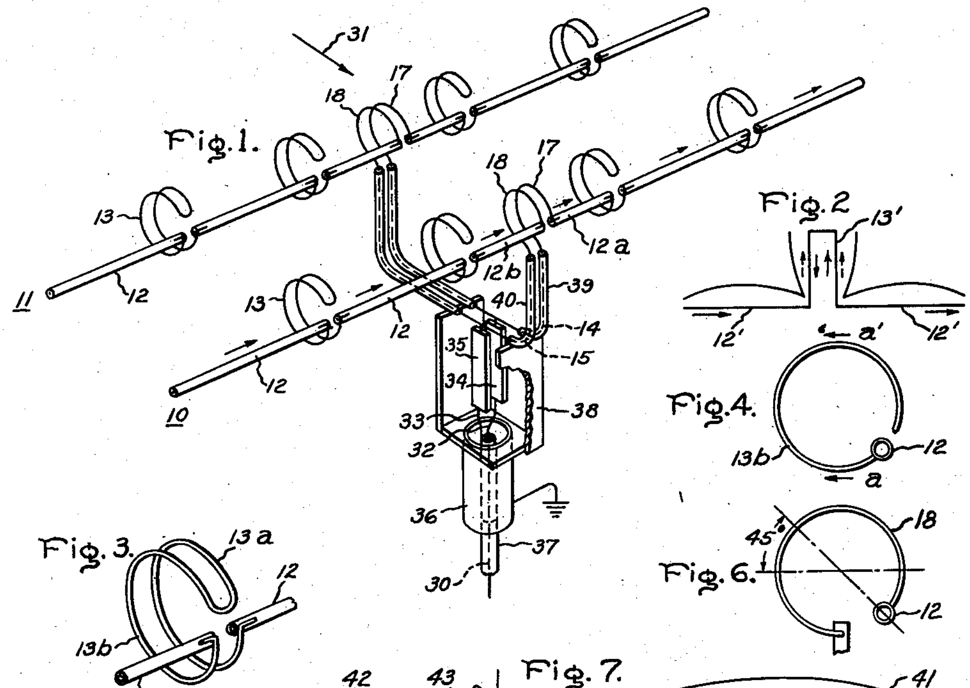

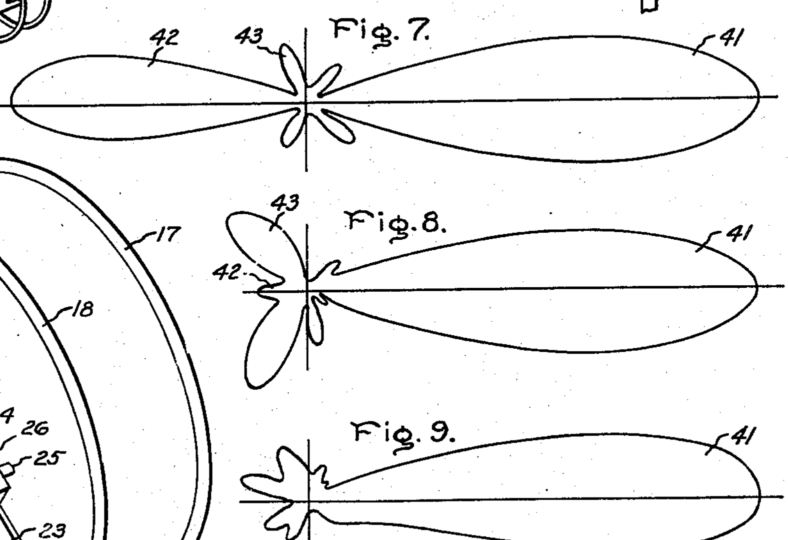

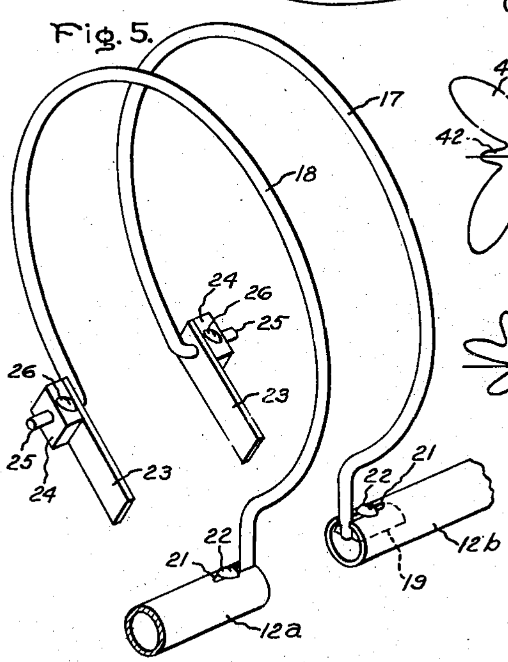

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2,380,333

HIGH FREQUENCY ANTENNA

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20 Claims. (Cl. 250—11)

This invention relates to high frequency antennas and more particularly to high frequency directive antennas especially suitable for studio-to-transmitter links in frequency modulation broadcasting systems.

In radio transmitter systems, the transmitter is usually located at a point relatively remote from the studio or other source of program. In radio systems employing frequency modulation, it has been found efficacious to convey programs to the point of transmission by means of a high frequency radio link for retransmission by the main transmitting apparatus. It is desirable to employ a highly directive antenna at the source of program which is directed toward the point of transmission.

Therefore, it is an object of my invention to provide a new and improved high frequency directive antenna particularly adapted for use with frequency modulation systems although not limited thereto.

It is another object of my invention to provide a new and improved high frequency directive antenna system which radiates substantially in only one direction and in a relatively narrow beam.

It is a further object of my invention to provide a new and improved high frequency directive antenna which is relatively simple and rugged in construction and which can be readily adjusted.

In accomplishing the foregoing objects, I have provided a horizontally polarized antenna comprising two separate horizontally disposed radiating assemblies each having a plurality of sections arranged colinearly or end to end. The separate assemblies are separated or spaced apart a distance of three quarters of a wavelength and connected together in such a way that the phase of the currents in the two assemblies differs by 270°. This spacing and current relationship causes one radiating assembly to act as a director with respect to the other and produces the desired unidirectional radiation characteristic. In order that each of the half wavelength radiating elements will have the same current phase as the other elements in the same assembly, phase inverting sections are used between them when more than two colinear sections are used. These phase inverting sections are disposed in such a configuration that voltages induced in the sections by current flowing in the radiating elements are in opposition and therefore tend to cancel out so that radiation from the phase inverting sections is substantially prevented.

In order to provide the necessary impedance matching, two pairs of adjustable impedance matching lines and two concentric interconnecting lines are provided between the two radiating assemblies. The concentric lines are disposed out of the plane of the assemblies. A third adjustable impedance matching line is connected between the common driving point on the interconnecting lines and the transmission line to the transmitter.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is a perspective view partly broken away of a complete antenna system embodying the principles of my invention; Fig. 2 is a diagrammatic representation illustrating certain phases of operation of a system of the general type embodying my invention; Figs. 3 and 4 are enlarged views of the phase inverting means illustrated in Fig. 1; Figs. 5 and 6 are enlarged views illustrating the connections from the signal source to the antenna; and Figs. 7, 8 and 9 are diagrammatic representations of typical operating characteristics for different arrangements of antennas embodying the principles of my invention.

Referring to Fig. 1 of the drawing, there is illustrated a horizontally mounted high frequency antenna system comprising two separate radiating assemblies 10 and 11, each having five colinear, or end-to-end, radiating elements or sections 12, each section or element being approximately one-half wavelength long.

In order to cause the instantaneous currents flowing in each of the sections or elements to flow in the same direction, the sections may be connected by phase inverters comprising current conducting members approximately one-half wavelength long, bent or folded back upon themselves to provide adjacent parallel members, the free ends engaging adjacent antenna elements. The resulting arrangement approximates a one-quarter wavelength transmission line. Such an arrangement is illustrated in Fig. 2 where colinear elements 12′ are connected by phase inverting means 13′. When such a system is energized, standing waves appear as indicated by the curved lines in Fig. 2 and the direction of currents through the system is as shown by the solid arrows. Inasmuch as the current flowing in the adjacent parallel sections of the phase inverting means 13′ are in opposite directions the electric fields created thereby tend to cancel and radiation from the phase inverters is minimized.

It has been determined, however, that the currents flowing in the sections 12' induce currents in both sides of the phase inverters which flow in the same direction in opposite sides of the loop as indicated by the dotted arrows in Fig. 2. The fields caused by induction in this manner do not cancel and therefore the inverters radiate in a horizontal plane, destroying to some extent the directivity of the antenna system.

In order to prevent such undesired radiation, the antenna illustrated in Fig. 1 is provided with phase inverting means 13 similar to those described above and illustrated in Fig. 2 but which are disposed in such a configuration, as illustrated in Fig. 3, that voltages induced in the parallel portions 13*a* and 13*b* of the inverters by the current flowing in the elements 12 cause currents to flow which are in opposition and therefore substantially cancel. Accordingly, radiation from the inverters 13 is substantially prevented. The reason for this substantial cancellation will be clear from an inspection of Fig. 4. Any radiation caused by current flow in sections 12 causes opposing voltages in diametrically opposite portions of the inverter loops as generally indicated by the arrows *a*, *a'*. The resulting currents are in opposition with respect to the terminals of the inverters and tend substantially to cancel. From this standpoint a configuration which is substantially circular is preferred. The more closely the loop produces a closed circle, the more nearly does cancellation take place. However, it is obvious that if the ends of the loop touch, the phase inversion is not accomplished. Furthermore, a certain amount of spacing must be allowed to prevent large capacity effects between the closed and open ends of the loops or phase inverters 13.

In order to distribute uniformly the energy supplied to the antenna system from the transmitter the assemblies 10 and 11 are center fed by introducing a driving voltage at substantially the midpoint of the center section of each of the assemblies. This may be accomplished by providing substantially one-quarter wavelength sections 12*a* and 12*b* so that the middle section of each of the assemblies is open at substantially the midpoint thereof. The assemblies 10 and 11 are then connected at the adjacent ends of the mid-sections 12*a* and 12*b* by interconnecting lines 14 and 15 terminating at each end in adjustable impedance matching lines 17 and 18, respectively. The lines 14 and 15 are preferably of the coaxial cable type except at the points of connection to the transmission line and to the matching lines in order to minimize radiation therefrom and provide weather protection.

The impedance of the matching lines 17, 18, which are electrically connected to the elements 12*a* and 12*b*, may be adjusted by the means shown in Fig. 5. There are provided laterally extending portions 19 integral or suitably attached to the members 17 and 18 and extending into the ends of the members 12*a* and 12*b*. The members or elements 12*a* and 12*b* may be slotted as indicated by the numeral 21 to receive the shank of a suitably threaded fastening member 22, which extends into threaded engagement with a suitably threaded opening in the portions 19.

The other ends of the matching lines 17, 18 may be adjustably connected to the concentric lines 14, 15 respectively, by means of suitable bars or straps 23 provided at one end with an enlarged portion or boss 24 having a suitable opening to receive lateral extending portions 25 of the matching lines. Suitably threaded fastening means indicated by the numeral 26 may be provided for clamping the matching lines at the desired positions. In order to vary the impedance, the spacing between the members 17 and 18 may be adjusted by moving the members with respect to the elements 12*a* and 12*b* and the interconnecting lines 14 and 15 and when the correct position is determined the members 22 and 26 may be tightened.

The matching lines are provided with a configuration similar to that of the phase inverters in order to prevent radiation therefrom in the same manner as previously described and should be slightly less than one-quarter wave-length long, the exact length being determined by experiment.

It has been found desirable, in order to minimize radiation in all undesired directions, so to dispose the matching lines and the inverters that a line drawn through the center of a loop and the axis of the antenna element to which it is connected lies at an angle of the order of 45° with respect to the horizontal, as indicated in Fig. 6.

If the concentric lines 14, 15 lie in the same plane as the radiating assemblies 10 and 11 it has been found that energy radiated from the assemblies 10 and 11 is reflected from the lines 14, 15 in horizontal directions and radiation in undesired horizontal directions is increased. In order substantially to eliminate reflection of energy from the lines 14, 15 in horizontal directions, the connecting lines are disposed out of the plane of the radiating assemblies. For convenience of erection of the antenna system, these lines are preferably disposed below the assemblies. Any energy reflected from the lines is therefore upward and not effective in the horizontal plane.

In order to convey energy to the interconnecting lines there is provided a transmission line 30 extending between the transmitter (not shown) and the concentric lines 14 and 15.

In order to supply energy to the radiating assemblies in such a manner as to cause the assembly 10 to act as a director for the assembly 11 and thereby to cause substantial radiation only in the direction shown by the arrow 31 in Fig. 1, the assemblies are spaced three-fourths of a wavelength apart and the transmission line 30 is connected to the feed lines 14, 15 at a point such that the distance from the point of connection to the directing assembly 10 is one-quarter of a wavelength shorter than the distance from the point of connection to the radiating assembly 11. If the assemblies are thus connected the phase of the current in the assemblies 10 and 11 differs by 270° which is the equivalent of a difference of 90°, or a quarter wavelength, in the opposite direction and the assembly nearest the point of connection acts as a director for the other assembly.

In order to provide a good impedance match between the transmission line 30 and the interconnecting lines 14 and 15, the transmission line preferably terminates in adjustable impedance means. For example, the transmission line may be terminated in conductors 32 and 33 which may be adjustably connected to the lines 14, 15 by means of suitable adjusting straps or bars 34 and 35 similar in nature to those illustrated in Fig. 5.

As is well understood, the outer conductor of the transmission line 30 is normally grounded. In order to prevent grounding the antenna there is provided an electrically conductive cylinder 36 larger in diameter than the transmission line and approximately one-quarter wavelength long. The lower end of the cylinder is connected electrically to the outer member 37 of the transmission line and is open at the upper end. As is well understood in the art the effect of this assembly is to introduce a high impedance between ground and the extreme end of the outer conductor 33 of the transmission line. In the illustrative form of my invention the adjustable members 34 and 35 and the end of the transmission line 30 are housed in a suitable housing 38 which is preferably of electrically conductive material disposed in engagement with the outer members 39 and 40 of the lines 14, 15, thereby grounding the outer members 39 and 40 of the lines 14 and 15, respectively, through the housing and the cylinder 36.

Reference may be had to Figs. 7, 8 and 9 for operating characteristics of the above described antenna. In Figs. 7 and 8 are illustrated representative radiation patterns obtained when employing inverters of the type shown in Fig. 2 and when the interconnecting lines lie in the plane of the assemblies 10 and 11. These figures represent such a system adjusted for minimum side lobes 43 and minimum back lobes 42, respectively. However, when side lobes are reduced, the back lobe is considerable and vice versa.

Fig. 9 shows a typical radiation pattern for the antenna system illustrated in Fig. 1. It will be noted that there is very little radiation in the direction opposite from the desired beam and all the side lobes are relatively small. Such an arrangement is particularly adapted to use in studio-to-transmitter links for frequency modulation systems because a very large proportion of the radiated energy is transmitted in a narrow beam which, of course, is directed at the point of transmission.

As is understood in the art, the narrowness of the beam of the antenna of the above described type is dependent upon the number of elements 12. While five have been illustrated, any desired number may be employed.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects. For instance, the above system is described in connection with a transmitter, but equally improved results are obtained when used as a receiving antenna. While two more sections may be employed, phase inverters are not required when only two sections are used in each assembly. Therefore, I aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A high frequency antenna system comprising at least three colinear elements, each of said elements being approximately one-half wavelength long, phase inverting means connecting adjacent elements and comprising a conductor approximately one-half wavelength long doubled upon itself to provide two substantially parallel members of substantially the same length, said parallel members being formed in loops at right angles to said elements, the opposite ends of said conductor engaging adjacent elements of said antenna at the ends thereof, whereby voltages induced in said members at opposite sides of said loop by current flowing in said elements are in substantial opposition and substantially no current flows in said members as a result of such induced voltages and radiation therefrom is substantially prevented.

2. A high frequency antenna system comprising at least three colinear elements, each of said elements being approximately one-half wavelength long, phase inverting means connecting adjacent elements and comprising a conductor approximately one-half wavelength long doubled at its midpoint upon itself to provide two substantially parallel members of substantially the same length, said members being formed in loops at right angles to said elements, the opposite ends of said conductor engaging adjacent elements of said antenna at the ends thereof, whereby voltages induced in said members at opposite sides of said loops by current flowing in said elements are in substantial opposition and substantially no current flows in said members as a result of such induced voltages and radiation therefrom is substantially prevented, said loops being so positioned in their respective planes that a line drawn through the center thereof and the axis of said elements lies at an angle of the order of forty-five degrees with respect to the horizontal.

3. A high frequency antenna system comprising at least three colinear elements, each of said elements being approximately one-half wavelength long, phase inverting means connecting adjacent elements and comprising a conductor approximately one-half wavelength long doubled on itself to provide two substantially parallel members of substantially the same length with the opposite ends of said conductor engaging adjacent elements at the ends thereof, said parallel members having the form of an approximately circular substantially closed loop at right angles to said elements.

4. A directive antenna having at least two coaxial elements extending in adjacent end-to-end relation, said elements operating in phase with respect to waves in space, the adjacent ends of said elements being connected together by a conductor having a length substantially equal to half of a wavelength at the frequency at which said antenna operates, said conductor having successive portions along its length from one end to the other extending in opposite directions with respect to each other and successive sections of each of said portions extending in opposite directions in a plane at right angles to said coaxial elements whereby said conductors are substantially equally and oppositely influenced by desired waves in space thereby to reduce the action of said antenna with respect to waves propagated in undesired directions.

5. A directive antenna comprising a pair of coaxial elements arranged end to end, adjacent ends of said elements being connected together by a conductor having a length equal to half of a wavelength at the frequency at which said antenna operates, said conductor being folded on itself at its midpoint, said midpoint lying adjacent to said elements, and the portions of said conductor opposite said midpoint extending therefrom about respective loops to said ends of the respective elements, said loops lying in a plane at right angles to said elements.

6. A directive antenna comprising a pair of coaxial elements arranged end to end, adjacent ends of said elements being connected together

by a conductor folded on itself at its midpoint, said midpoint lying adjacent said elements, and the portions of said conductor opposite said midpoint being formed in loops at right angles to said elements, said loops having a peripheral length equal to a quarter of the operating wavelength of said antenna.

7. A directive antenna having coaxial elements spaced in end-to-end relation in a colinear array, radio apparatus connected to the midpoint of said array, and means to operate all of said elements in phase, said means comprising conductors connected between adjacent ends of adjacent elements, said conductors having a length equal to half a wavelength at the frequency at which said antenna operates, each of said conductors being folded upon itself at its midpoint and formed in a loop in a plane at right angles to said array.

8. In an antenna having coaxially arranged radiating elements, each of said elements having a length equal to half a wavelength at the frequency at which the antenna operates, adjacent ends of adjacent elements being connected together by a nonradiating conductor having an electrical length equal to half said wavelength, said conductor being doubled on itself at its midpoint, the halves thereof extending from said midpoint first in one direction and then in the opposite direction in a plane at right angles to said radiating elements whereby electromotive forces induced in the oppositely extending portions of said halves by fields produced by said elements neutralize each other thereby preventing the production of currents in said conductor which produce undesired radiation therefrom.

9. An antenna comprising a plurality of coaxial elements arranged end to end, each of said elements having a length equal to half the operating wavelength, conductors joining adjacent ends of adjacent of said elements, said conductors each being folded on itself at its midpoint and formed in a loop extending from said midpoint to the respective ends of said elements, said loop lying in a plane at right angles to said elements, high frequency apparatus, and connections extending from the midpoint of the middle of said elements to said apparatus, said connections being formed in a loop parallel to said first mentioned loops, and the peripheral length of all of said loops being adjusted for maximum directivity of said antenna.

10. A directive antenna comprising two parallel arrays, each array comprising a plurality of coaxial half wavelength elements arranged end to end, means to energize all of said elements of each array in phase, said means comprising transmission lines extending to each array, having lengths proportioned to reduce maximum effect of said antenna in the plane of said arrays, the conductors of said transmission lines being disposed out of said plane defined by said arrays thereby to reduce the effect of said conductors on the directivity characteristics of said array in said plane.

11. A directive antenna comprising two parallel arrays, each array comprising a plurality of coaxial half wavelength elements arranged end to end, means to energize all of said elements of each array in phase, and to energize the different arrays in phase relation to produce maximum effect in the plane defined by said arrays said means comprising transmission lines extending to each array, the conductors of said transmission lines being disposed out of said plane defined by said arrays thereby to reduce the effect of said conductors on the directivity characteristics of said array and the portion of each of said conductors adjacent said arrays extending about a loop in a plane at right angles to the array to reduce the induction of current therein by waves in space.

12. A directive antenna comprising two parallel arrays, each array comprising a plurality of coaxial half wavelength elements arranged end to end, means to energize all of said elements in phase to produce maximum radiation in the plane defined by said arrays, said means comprising transmission lines extending to each array, the conductors of said transmission lines being disposed out of said plane defined by said arrays thereby to reduce the effect of said conductors on the directivity characteristics of said array in said plane and the portion of each of said conductors adjacent said arrays extending about a loop in a plane at right angles to the respective array to reduce the induction of current therein by waves in space, the adjacent elements of each array being connected together by conductors each doubled on itself at its midpoint and formed in a loop parallel with said first loop and the peripheral length of all of said loops being adjusted for optimum directivity of said antenna.

13. A directive antenna comprising two parallel arrays, each array comprising a plurality of half wavelength elements arranged end to end, adjacent ends of the elements in each array being connected together by conductors of length to maintain said elements in phase, each of said conductors being doubled on itself at its midpoint and formed in a loop at right angles to said elements, the centers of said loops lying in a plane intersecting the plane defined by the arrays at an angle of forty-five degrees at the position of the elements joined by the respective loops.

14. An antenna system comprising two assemblies arranged in parallel space relation, each assembly comprising a number of colinear elements arranged end to end, high frequency apparatus connected to each of said assemblies through respective transmission lines differing in length by an odd multiple of a quarter of a wave length of the wave on which said antenna operates whereby said antenna has maximum effect in a direction at right angles to said assemblies and in the plane of said assemblies, and said lines lying substantially entirely out of the plane of said assemblies thereby to have minimum effect upon the field pattern of said antenna in space.

15. An antenna system comprising two assemblies arranged in parallel space relation, each assembly comprising a number of colinear elements arranged end to end, high frequency apparatus connected to each of said assemblies through respective transmission lines differing in length by an odd multiple of a quarter of a wave length of the wave on which said antenna operates whereby said antenna has maximum effect in a direction at right angles to said assemblies and in the plane of said assemblies, said lines lying substantially entirely out of the plane of said assemblies and each conductor thereof extending to its respective assembly about a loop in a plane at right angles to the respective assembly whereby voltages induced in opposite sides of said loop by waves on which

the antenna operates are opposing and said lines and loops have minimum effect upon the field pattern of said antenna in space.

16. An antenna system comprising two assemblies arranged in parallel space relation, each assembly comprising a number of colinear elements arranged end to end, high frequecy apparatus connected to each of said assemblies through respective transmission lines differing in length by an odd multiple of a quarter of a wave length of the wave on which said antenna operates whereby said antenna has maximum effect in a direction at right angles to said assemblies and in the plane of said assemblies, and said lines lying substantially entirely out of the plane of said assemblies, each of said lines comprising a pair of conductors extending at the antenna end thereof about a loop to the respective assembly, said loops lying at right angles to the respective assembly whereby voltages induced in said conductors at opposite sides of said loops by desired waves in space are opposing and said conductors have minimum effect upon the field pattern of said antenna in space.

17. An antenna system comprising two assemblies arranged in parallel space relation, each assembly comprising a number of colinear elements arranged end to end, high frequency apparatus connected to each of said assemblies through respective transmission lines differing in length by an odd multiple of a quarter of a wave length of the wave on which said antenna operates whereby said antenna has maximum effect in a direction at right angles to said assemblies and in the plane of said assemblies, and said lines lying substantially entirely out of the plane of said assemblies, each of said lines comprising a pair of conductors extending at the antenna end thereof about a loop to the respective assembly, said loops lying at right angles to the respective assembly whereby voltages induced in said conductors at opposite sides of said loops by desired waves in space are opposing and the circumferences of said loops and the spacing between said conductors being adjusted to match the impedance of said lines to that of said assembly.

18. An antenna comprising two parallel assemblies, each assembly comprising an odd number of colinear elements arranged end to end, each of said elements having a length equal to half of a wavelength of the wave on which said antenna operates, and the middle element of each assembly being broken at its midpoint, high frequency apparatus connected through respective transmission lines to each assembly, said lines comprising conductors extending about loops at right angles to the respective assembly to opposite sides of said break, conductors connecting adjacent ends of adjacent elements of each assembly, said conductors each having a length equal to a half wavelength and doubled at its midpoint on itself and extending from said midpoint about a loop parallel with said first mentioned loops, said lines having length sufficiently different from each other to produce maximum effect of said antenna in a direction in the plane of said assemblies, said lines lying outside of said plane to reduce the effect thereof on the space pattern of said antenna in said plane and all said conductors extending about loops having opposing voltages induced therein at opposite sides of the respective loop by desired waves in space thereby to neutralize and reduce the effect of said conductors on said space pattern.

19. An antenna comprising two parallel assemblies, each assembly comprising an odd number of colinear elements arranged end to end, each of said elements having a length equal to half of a wavelength of the wave on which said antenna operates, and the middle element of each assembly being broken at its midpoint, high frequency apparatus connected through respective transmission lines to each assembly, said lines comprising conductors extending about loops at right angles to the respective assembly to opposite sides of said break, conductors connecting adjacent ends of adjacent elements of each assembly, said conductors each having a length equal to a half wavelength and doubled at its midpoint on itself and extending from said midpoint about a loop parallel with said first mentioned loops, said lines having length sufficiently different from each other to produce maximum effect of said antenna in a direction in the line of said assemblies, said lines lying outside of said plane to reduce the effect thereof on the space pattern of said antenna in said plane and said loops having centers outside said plane and in a direction from the respective assembly in a plane at right angles thereto to reduce the effect of said loops on said space pattern.

20. In an antenna, the combination of two coaxial antenna elements extending in adjacent end to end relation and operating in phase with respect to waves in space, adjacent ends of said elements being connected together by a conductor having a length equal to half the length of the wave on which said antenna operates, said conductor being doubled on itself at its midpoint whereby the opposite halves of said conductor have opposing effects with respect to desired waves and said opposite halves extending equally in opposite directions in a plane at right angles to said elements.

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