

June 6, 1944.

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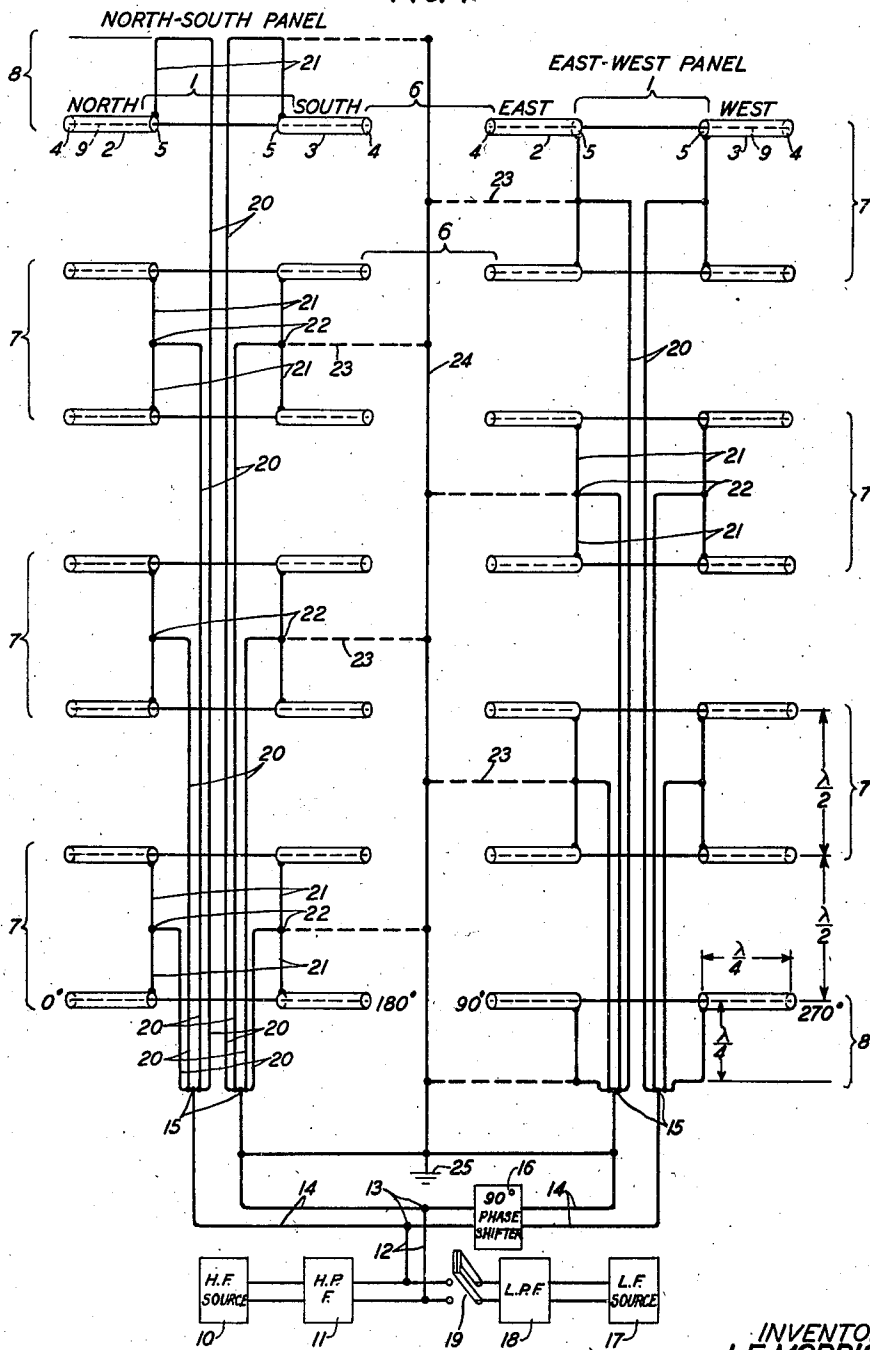
2,350,916

ULTRA-SHORT WAVE ANTENNA SYSTEM

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2 Sheets-Sheet 1

FIG. 1



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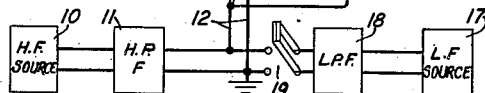
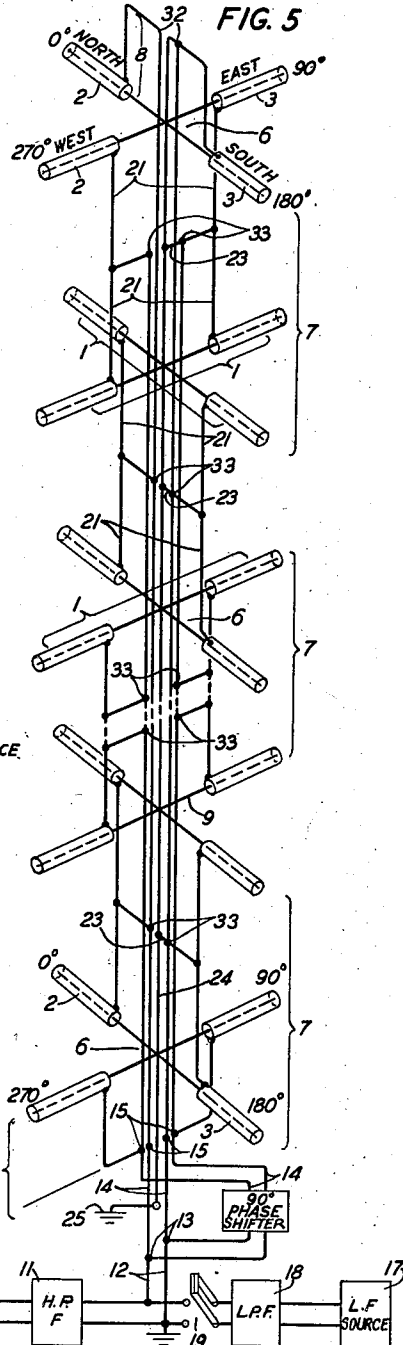
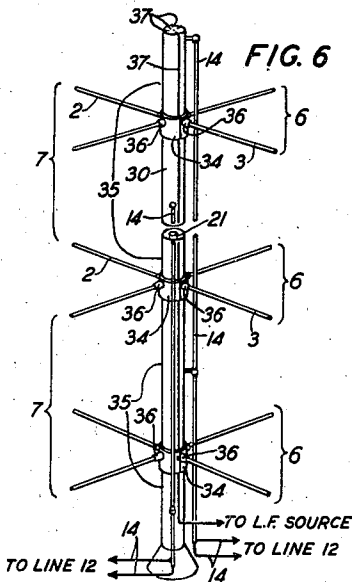
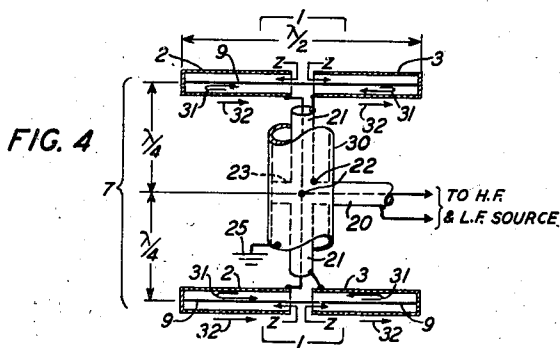
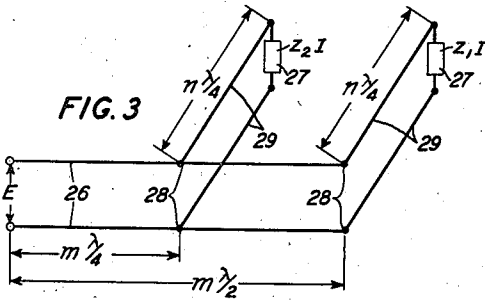
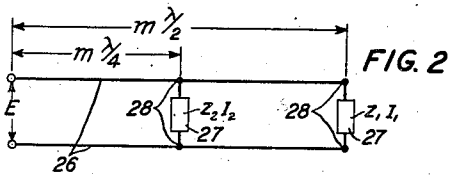
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ULTRA SHORT WAVE ANTENNA SYSTEM

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16 Claims. (Cl. 250—11)

This invention relates to antenna systems and more particularly to antenna arrays for radiating or receiving waves having a relatively high frequency.

As disclosed in Patent 2,086,976, G. H. Brown, July 13, 1937, the so-called turnstile antenna unit comprising a pair of horizontal doublets arranged in space quadrature and energized in phase quadrature functions to produce non-directional radiation in a horizontal plane, provided that the currents in the two doublets are, as stated in the patent to Brown, equal. If the currents are slightly unequal, the theoretical directive characteristic, instead of being circular as illustrated by Fig. IV of the above-mentioned patent, will be elliptical; and if the currents are greatly unequal the characteristic may even resemble the well-known hour-glass diagram whereby the field intensities at points equally distant from the broadcast antenna will vary greatly. Also, an array or stack of such turnstile units produces in the vertical plane, assuming equal currents in the several units, a low beam, and as shown by Fig. V of the above-mentioned patent, the gain increases with the number of turnstile units. It has been found, however, that the theoretical directive characteristic and the theoretical gain are not realized in actual practice, primarily because mutual coupling and other factors cause the doublet antennas to differ in impedance with the result that the doublet currents vary greatly. Also, in practice, considerable difficulty has been experienced during the winter season in obtaining effective radiation with antenna systems resembling that mentioned above because of frequent sleet accumulation on both the horizontal and vertical elements of the system. In addition, the sleet or ice load has on occasion mechanically impaired antennas of this type.

It is one object of this invention to improve ultra-short wave radio transmission and reception.

It is another object of this invention to secure, in actual practice, properly phased equiamplitude antenna currents in a multiple unit array for the purpose of improving the gain of the array.

It is a further object of this invention to provide means for removing sleet and static currents from the horizontal and vertical portions of a system such as a vertical array of horizontal radiators.

It is still another object of this invention to provide a rugged durable multiunit vertical antenna array comprising horizontal radiators.

According to one embodiment of this invention

the north-south doublets constituting one vertical panel of the turnstile array are arranged in groups or sections of two each, and the east-west doublets constituting the other panel of the array are similarly arranged. While the doublets are termed "north-south" and "east-west," the orientation of these doublets may not, of course, coincide with the four compass directions. Separate transmission lines, hereinafter termed "panel" lines, connect the doublets in the two panels to the same junction point on the main line from the transmitter. More specifically, the doublets in each section are connected through individual quarter wave-length coaxial lines hereinafter termed "branch" lines, to the same point on the associated panel line; and the doublets in adjacent sections of the same panel are connected to the panel line at points spaced a wave-length apart and electrically distant an even multiple of a quarter wave-length from the main line junction mentioned above, whereby in each panel the radiators are properly phased and the current in all doublets has the same amplitude.

Considering each doublet, the two radiators comprise hollow metallic tubes closed at one end. A high resistance conductor connects the closed ends of the two tubes, the arrangement being such that the two radiating tubes of each doublet and enclosed heater wire constitute a series circuit for the sleet-melting current, and the inner surface of each tube and the portion of the heater wire adjacent thereto constitute a high impedance for radio frequency, whereby the radio frequency flows only on the outer radiating surface of the tube. The two vertically positioned coaxial quarter wave-length branch lines in each section are enclosed in a grounded cylindrical vertical shield which is directly connected to the outer conductor of the two branch lines at their junction point so that the two radiating tubes are each connected to ground through a path of low impedance for frequencies other than the operating carrier and side-band frequencies for the purpose of draining or removing static currents. At the same time, the impedance between ground and each radiator is relatively high at the operating frequency. Also, the several vertical shields are co-linearly arranged and articulated to form a mast, and the mast is preferably equipped with sleet-melting lines each comprising a copper tube enclosing a heater conductor and extending vertically along the inner or outer mast surface.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawings on which

like reference characters denote elements of similar function and on which:

Fig. 1 illustrates one embodiment of the invention;

Figs. 2 and 3 are diagrams used for explaining the operation of the system of Fig. 1;

Fig. 4 is a detailed schematic illustration of an antenna section included in the system of Fig. 1;

Fig. 5 illustrates the electrical features of another embodiment of the invention; and

Fig. 6 illustrates certain mechanical features of the embodiment illustrated by Fig. 5.

Referring to Fig. 1, reference numerals 1 designate half wave-length horizontal antenna doublets each comprising two quarter wave-length tubular radiators 2 and 3 colinearly arranged and each having a closed end 4 and an open end 5. The north-south doublets are vertically spaced a half wave-length apart and are included in one vertical plane and the east-west doublets are similarly spaced in a vertical plane perpendicularly related to the north-south vertical plane. The doublets are so positioned that each north-south doublet is included in a horizontal plane containing an east-west doublet and forms therewith a turnstile unit or subarray 6. The doublets 1 in the north-south panel, except the top doublet, and the doublets in the east-west panel, except the bottom doublet, are arranged, as is explained more fully below, in groups or central sections 7, each comprising a pair of vertically spaced doublets. The top and bottom doublets just referred to are included in an antenna end or half section 8. In the case of each doublet a high resistance heater wire 9 is positioned within radiators 2 and 3, and connected to the closed radiator ends 4.

Reference numeral 10 designates a source of radio frequency energy which is connected through a high frequency pass filter 11 and main line 12 to the input terminals 13 of the north-south and the east-west panel transmission lines 14. Reference numerals 15 designate the output terminals of the panel lines 14 and numeral 16 denotes a 90 degree phase shifter included in the east-west panel line 14. A low frequency or direct current sleet-melting source 17 and associated low-pass filter 18 may be connected by means of switch 19 to the main line 12 and the panel lines 14. In each panel, separate "section" lines 20 connect the panel line 14 to each central section 7 and separate quarter wave-length branch lines 21 are included in each section between the doublets 1 and the output terminals 22 of the section line 20. The doublet in the top end section is similarly connected through a quarter wave-length line 21 to a separate section line 20 and the doublet in the bottom end section of the east-west panel is connected through a quarter wave-length line 21 either directly to the panel line or through a section line of negligible length. The paths extending from terminals 13 to the various output terminals 22 of the section lines 20 each have a length equal to an even multiple of a quarter wave-length, the difference in length between the section lines 20 connected to adjacent sections in the same panel being one wave-length. One output terminal 22 of each section line 20 is connected by connection 23 of negligible lengths and a cylindrical shield represented by conductor 24 to the ground 25. As described below and illustrated in Figs. 4 and 6 all transmission lines are preferably of the coaxial type. Also, the branch lines are preferably enclosed by the cylindrical shield mentioned above.

Considering the radio frequency operation, energy is supplied through filter 11 over lines 12 and 14 directly to the section lines 20 in the north-south panel and through quadrature phase shifter 16 to the section lines 20 in the east-west panel. In each section 7 the energy flows from terminals 22 of the section line 20 in parallel through the branch quarter wave-length lines 21 whereby the two corresponding quarter wave-length radiators in each section 7 of each panel are energized in phase and the four radiators in each central turnstile unit or subarray 6 are energized in quadrature phase. In each end section 8, the energy from the section line 20 flows through the quarter wave-length line 21 to the radiators 2 and 3 of the single doublet 1. Also, since the section lines 20 connected to adjacent sections in the same panel differ in length a wave-length, all corresponding radiators in the panel are energized in phase. Thus assuming the currents in the "north" radiator have zero phase, the currents in the "south" radiator have 180 degree phase, and the currents in the "east" and "west" radiators have, respectively, either 90 and 270 degree phases, or 270 and 90 degree phases, as indicated on the drawings. As explained in Patent 2,086,976 mentioned above, the quadrature energization of the quadrature radiators produces, assuming the currents are equal, a circular horizontal directive characteristic. Since the electrical distance from terminals 22 of each section line 20 to the terminals 13 is an even multiple of a quarter wave-length, the voltage effective at the various sets of terminals 22 in the sections of both panels has an intensity substantially equal to that of the input voltage at terminals 13. This follows from the fact that in the case of a line having a length equal to an even multiple of a quarter wave-length, the ratio of the input voltage to the output voltage is unity, as disclosed in the text-book "Communication Networks" by Guellemine, vol. 2, page 65.

Referring now to Figs. 2 and 3, it will be shown that, in accordance with one feature of the invention, the currents in all doublets 1 in both panels of the system of Fig. 1 have the same amplitude, regardless of the difference in impedance among the doublets. In each of Figs. 2 and 3, reference character E denotes a voltage of constant intensity and reference numeral 26 designates a transmission line across which the impedances 27, each representing a doublet impedance, are connected. The impedances are connected to points 28 electrically distant from the source E an even multiple of a quarter wave-length, the character m on the drawing denoting an even integer. In the schematic representation of Fig. 2 the doublet impedances 27 are connected directly to the selected points as in the system of Patent 2,086,976 mentioned above but in the system of Fig. 3 the impedances 27 are connected to the selected points 28 through individual branch lines 29, each a quarter wave-length long, as in the system of Fig. 1, the reference letter n designating an odd integer. The impedances 27 in each of Figs. 2 and 3 are assumed to be different, as indicated by the reference characters Z_1 and Z_2 .

As is apparent from the description of Fig. 1 given above the voltages at the points 28 in the systems of Figs. 2 and 3 are each equal to the voltage of the source E and therefore in each system the voltages at points 28 are equal to each other. Also, since the voltage of source E is by design constant the voltages effective at points

28 are constant. In the system of Fig. 2 the currents I_1 and I_2 flowing through the parallel impedances 27 are, in accordance with Ohm's law, not equal since these impedances are directly connected to the line 26 and since the impedances Z_1 and Z_2 are unequal. On the other hand, the currents I_1 flowing through the two impedances 27 in the system of Fig. 3 are equal, although these impedances are different, since in the case of a quarter wave-length line terminated by an impedance, the current through the terminating impedance is independent of the value of the termination impedance and remains constant provided the voltage input to the line remains constant. See the text-book "Communication Network" referred to above, page 65. Hence in the system of Fig. 1, regardless of the differences among the doublet impedances, the doublet currents are maintained equal in amplitude inasmuch as the voltages effective at all section line output terminals 22 are each constant and equal to the input voltage at terminals 13, and the input terminals of each doublet 1 are connected through a quarter wave-length line to its associated set of terminals 22. In practice, as already indicated, the doublet impedances ordinarily differ from each other because among other reasons no two doublets occupy the same physical position with respect to the other doublets and, considering any two doublets, the mutual coupling between one doublet and the remaining doublets is substantially different from the mutual coupling between the other doublet and the remaining doublets. Moreover, changes in impedance often occur after long continued use as a result of deterioration and sagging of the antenna elements.

Referring now to Fig. 4, the operation of the sleet-melting circuit and the balance-to-ground arrangement used in the system of Fig. 1 will be explained. The coaxial quarter wavelength lines 21 in Fig. 4 correspond in function to the similarly designated branch quarter wave-length lines in Fig. 1, the upper doublet 1 in Fig. 4 being connected to one line 21 and the lower doublet 1 being connected to the other line 21. The input terminals of these branch lines are directly connected to, and in fact coincide with, the output terminals 22 of the section line 20 which, as explained above in connection with Fig. 1, is connected to the high frequency source 19 and the low frequency source 17. Also, at the junction of the two lines 21, the outer conductors of these two lines are directly connected to the ground 25 through connection 23 and the shield 30. Considered in a different manner, the two lines 21 constitute a half wave-length line connected between the input terminals of the two doublets in the section, the section line 20 being connected to the mid-point of the half wave line and the mid-point of the outer conductor of the half wave-length line being grounded.

In operation, considering one doublet of Fig. 4, sleet-melting current flows in series along one conductor of section line 20, one radiator 2, heater conductor 9, the other radiator 3 and then along the other conductor of section line 20 as indicated by the arrows 31 in Fig. 4. The radio frequency energy, however, supplied by the same section line 20 flows substantially only along the outer surfaces of the two radiators 2 and 3 constituting each doublet 1 as indicated by arrows 32, inasmuch as the inner surface of each quarter wave-length radiator and enclosed heater conductor constitute a short-circuited quarter wave-

length line. In other words, at the operating frequency the impedance Z , Fig. 4, looking into each tubular radiator, is exceedingly high. In the case of each doublet, the right-hand radiator 3 is connected for currents, such as static current, having a frequency other than the operating frequency, to ground 25 through a conductive path of negligible impedance comprising the outer conductor of line 21, connection 23 and shield 30. The left-hand radiator 2 is also connected to ground 25 for these frequencies since heater wire 9 constitutes a conductive path of negligible impedance between the two radiators 2 and 3. In addition, the impedances between ground and the radiators of each doublet are relatively high and substantially balanced at the operating frequency. More specifically, the impedance between the left-hand radiator 2 and the ground 25 is relatively high since this radiator is connected to the inner conductor or ungrounded side of section line 20; and the impedance between the right-hand radiator 3 and ground 25 is relatively high inasmuch as the input terminal of this radiator is connected to ground 25 through the outer conductor of branch line 21 which has a length of a quarter wave-length. Similarly, in the system of Fig. 1, sleet-melting current flows along the conductors 9 when the low frequency source 17 is connected to the system by means of switch 19. The low frequency pass filter 18 functions to block the flow of high frequency energy to the low frequency source 17 and the high frequency pass filter 11 functions to block the flow of low frequency energy to the high frequency source 19. The right and left-hand radiators 2 and 3 are connected together by conductor 9 and to ground 25 for lightning and static currents. Also, the radiators 2 and 3 of each doublet are connected through a high impedance to ground, the radiator 3 being connected through the outer quarter wave-length conductor of branch line 21 and connection 23 to the grounded shield 24, whereby the radiators of all doublets are balanced to ground at the operating frequency.

The embodiment illustrated by the perspective views, Figs. 5 and 6, is the same as that illustrated by Fig. 1 except that instead of separate section transmission lines 20 for the various sections 7, the alternate sections 7 are connected to the same panel line 14. Thus, referring to Fig. 5, the north-south sections 7 are bridged across the north-south panel line 14 at points 33 spaced a wave-length apart, and the east-west sections 7 are connected to the east-west panel line 14 at points 33 spaced a wave-length apart whereby the corresponding radiators are energized in phase. As shown on the drawings, the electrical path from any pair of points 33 to the input terminals 13 is an even multiple of a quarter wave-length whereby the effective voltages at these points are equal and constant. As in the system of Fig. 1, the doublets are each connected to the associated panel line through a quarter wave-length branch line 21 and, in operation, the doublet currents remain constant irrespective of impedance variations, as explained in connection with Figs. 2 and 3. The sleet-melting arrangement and the balance-to-ground arrangement included in the system of Fig. 1 and described in detail in connection with Fig. 4 are also included in the embodiment of Fig. 5 and Fig. 6. Thus one terminal 33 in each section 7 is connected by connection 23 to the ground conductor 24 (Fig. 5) or the grounded shield 30 (Fig. 6). As shown in Fig. 6, the colinear ver-

tical tubes 30 are each a half wave-length long and, in each section 7, each encloses or shields the two associated branch lines 21. The shields 30 are articulated by sleeves 34 and form a strong flag pole type supporting structure 35, the doublets being attached through insulators 36 to the articulated grounded supporting structure. Hence the doublets are series excited and not, as in the system of the Brown patent mentioned above, shunt excited. Reference numerals 37 designate sleet-melting coaxial lines each comprising a copper outer conductor and a high resistance inner conductor. These lines extend longitudinally along the vertical structure 36 and are connected to the low-frequency sleet-melting source 17.

Although the invention has been explained in connection with certain specific embodiments, it should be understood that it is not to be limited to these embodiments since other apparatus may be employed in successfully practising the invention. Moreover, while the antenna of the invention is especially suitable for use with ultra-short waves as, for example, waves having a wave-length less than twelve meters, it may be used for transmitting or receiving waves having any operating wave-length.

What is claimed is:

1. In a radio system, an array comprising three similar antenna units spaced along a given direction or axis, each unit comprising two antenna doublets positioned in the same plane and extending in different directions, a first line connecting two corresponding doublets in the central unit and one of the remaining units, a second line connecting the other doublet in the central unit and the corresponding doublet in the other of the remaining units, said lines each having a length equal to a half wave-length or an odd multiple thereof, a translation device, a phase shifting means, and separate transmission lines connecting the mid-point of the first line directly, and the mid-point of the second line through said means, to said device.

2. A system in accordance with claim 1, said last-mentioned transmission lines each having an electrical length equal to an even multiple of a quarter wave-length.

3. In a radio system, a turnstile array comprising at least three vertically spaced subarrays each comprising two perpendicularly related horizontal doublets, a first half wave-length branch line connecting one pair of corresponding doublets of the central subarray and the uppermost subarray, a second half wave-length branch line connecting the other doublet in the central subarray and the corresponding doublet in the remaining subarray, a translation device, a quadrature phase shifter, a first transmission line connecting said device directly to the mid-point of one branch line, and a second transmission line connecting said device through the phase shifter to the mid-point of the other branch line.

4. A system in accordance with claim 3, said last-mentioned transmission lines each having a length equal to an even multiple of a quarter wave-length.

5. In a radio system, a turnstile antenna array comprising a plurality of horizontal doublets spaced a half wave-length apart in a vertical plane and constituting a first antenna panel, a second plurality of horizontal doublets spaced a half wave-length apart in another vertical plane and constituting a second antenna panel, each doublet of one panel and a doublet of the other

panel being included in the same horizontal plane and constituting a subarray, a plurality of half wave-length vertical branch lines each included between a different pair of adjacent subarrays and connecting one pair of similarly oriented doublets in said subarrays, the alternate branch lines being connected to doublets of the same panel, a translation device, a quadrature phase shifter, a panel line connecting the mid-points of one of said alternate branch lines directly to said device, and another panel line connecting the mid-points of the remaining set of branch lines through said quadrature phase shifter to said device.

6. A system in accordance with claim 5, the mid-points of the branch lines in each set being connected directly to the panel line at points spaced a wave-length or a multiple thereof apart.

7. A system in accordance with claim 5, separate section lines of different length connecting the mid-points of the branch lines in each set to the same point on the main line, the difference in length between the section lines associated with adjacent branch lines being one wave-length or a multiple thereof.

8. A system in accordance with claim 5, supporting and shielding means for said system comprising a plurality of articulated metallic tubular members, each member enclosing a different vertical half wave-length branch line and attached to the similarly oriented spaced doublets connected to said branch line.

9. In a radio system, an antenna member comprising two cylindrical tubular elements each a quarter wave-length long and each having an open and a closed end, the open ends of said elements facing each other, a high resistance conductor coaxially positioned within said elements and connected to the closed ends of said elements, each element and the enclosed portion of said conductor constituting a short-circuited quarter wave line having an exceedingly high impedance at the operating frequency a source of high frequency energy, a source of sleet-melting energy, and a common coaxial line connecting said sources between the open ends of said elements whereby the high frequency energy is confined to the outer radiating surfaces of said elements, and the sleet-melting current flows in series through said elements and said high resistance conductor.

10. In a radio system, a doublet antenna, a translation device, a coaxial line connecting two spaced points on said doublet to said device, the terminal of the outer conductor of said line adjacent said doublet being grounded only through a section of said conductor a quarter wave-length long or an odd multiple thereof, whereby the impedance between ground and each of said points on said doublet is relatively high and said impedances are substantially balanced.

11. In a radio system, a pair of doublets each comprising a pair of colinear quarter wave-length radiators, a half wave-length coaxial line connecting the input terminals of said doublets, a grounded supporting and shielding means comprising a metallic tube having a length of one-half wave-length and enclosing said line, each doublet being attached to and insulated from a different end of said tube, the mid-points of the conductors of the half wave-length line being connected to a transmitter and the mid-point of the outer conductor of said half wave-length line being directly connected to said tube, whereby the corresponding radiators of said doublets are

energized in phase and the impedance between each radiator and the ground is relatively high.

12. A system in accordance with claim 11, each radiator comprising a tubular member having a closed end, a conductor coaxially positioned within the radiators of one of the doublets and connected to the closed ends of the radiators of said doublet, whereby each radiator of said doublet is connected to ground through a path of substantially zero impedance for frequencies other than the operating frequency and through a high impedance for the operating frequency.

13. A system in accordance with claim 11, each radiator comprising a tubular member having a closed end, a conductor coaxially positioned within the radiators of one of the doublets and connected to the closed ends of the radiators of said doublet, the mid-points of the conductors of the half wave-length line being connected to a source of sleet-melting current, vertical sleet-melting lines attached to and extending longitudinally along the metallic shielding tube, and said sleet-melting lines being connected to the sleet-melting source.

14. A turnstile antenna including in combination a supporting mast, a plurality of radiator elements, each of said elements being broadly responsive to currents covering a band of frequencies and each including an inner conductor, a concentric conductive sleeve shorter than said inner conductor and surrounding said inner conductor, means connecting said inner conductor and said sleeve at their outer ends, said inner conductors being secured to said mast to form a plurality of horizontal arrays of four elements each, said arrays being spaced apart a half wave length, said four elements of each array being respectively located in vertical planes disposed at 90° intervals about said mast, and means for applying quadrature phase currents to said four elements and cophasal currents to the elements of said vertical planes.

15. A turnstile antenna including in combination a supporting mast, a plurality of radiator elements, each of said elements being broadly responsive to currents covering a band of frequencies and each including an inner conductor, a concentric conductive sleeve shorter than said inner conductor and surrounding said inner conductor, means connecting said inner conductor and said sleeve at their outer ends, said inner conductors being secured to said mast to form a plurality of horizontal arrays of four elements each, said arrays being spaced apart a half wave length, said four elements of each array being respectively located in vertical planes disposed at 90° intervals about said mast, and four transmission lines connected to said four elements respectively to apply quadrature phase currents to said four elements and cophasal currents to the elements of said vertical planes.

16. A turnstile antenna including in combination a supporting mast, a plurality of radiator elements, each of said elements being broadly responsive to currents covering a band of frequencies and each including an inner conductor, a concentric conductive sleeve shorter than said inner conductor and surrounding said inner conductor, means connecting said inner conductor and said sleeve at their outer ends, said inner conductors being secured to said mast to form a plurality of horizontal arrays of four elements each, said arrays being spaced apart a half wave length, said four elements of each array being respectively located in vertical planes disposed at 90° intervals about said mast, the adjacent elements in each of said vertical planes being connected by serially connected quarter wave length lines, full wave length lines connecting the junction of said quarter wave lines, and transmission lines for applying currents to said full wave length lines.

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