

March 25, 1941.

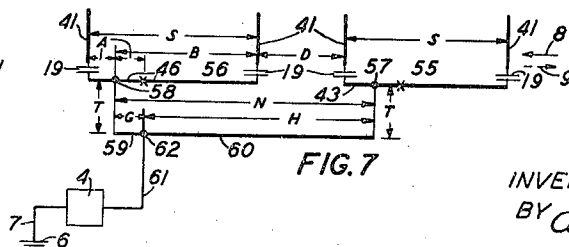
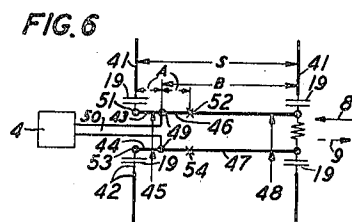
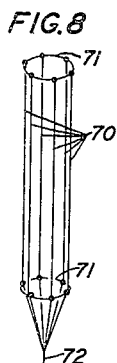
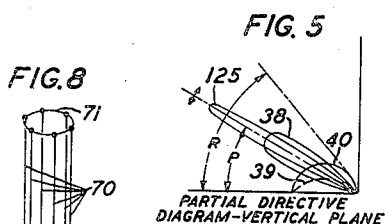
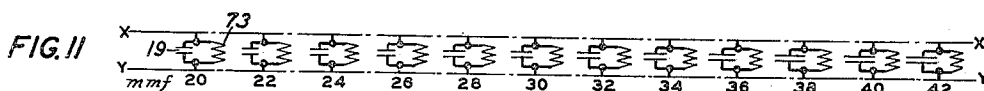
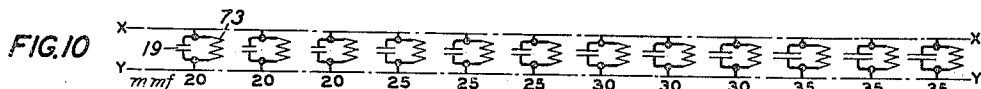
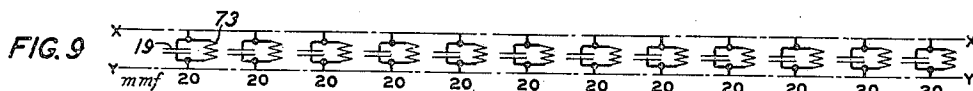
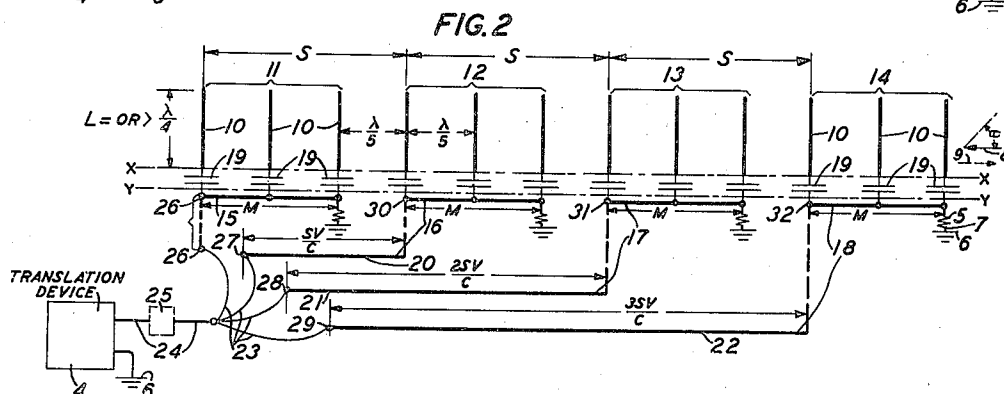
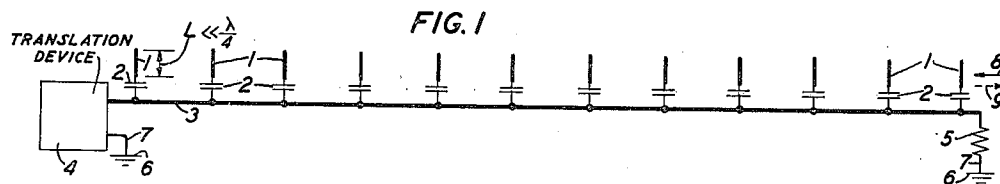
A. C. BECK ET AL.

2,236,393

DIRECTIONAL ANTENNA

Filed March 1, 1939

3 Sheets-Sheet 1



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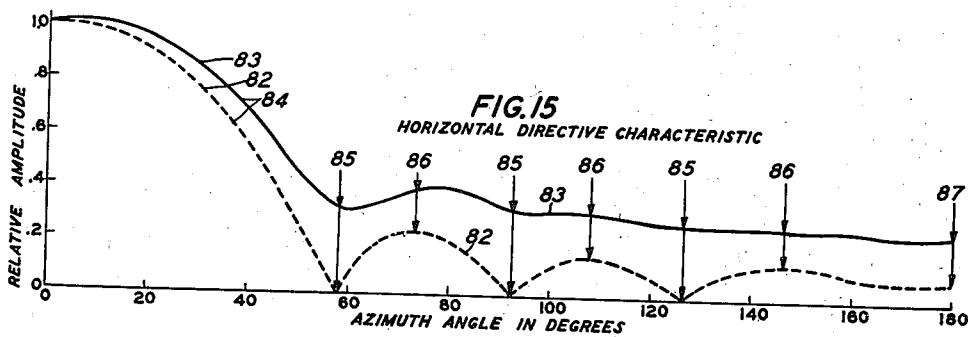
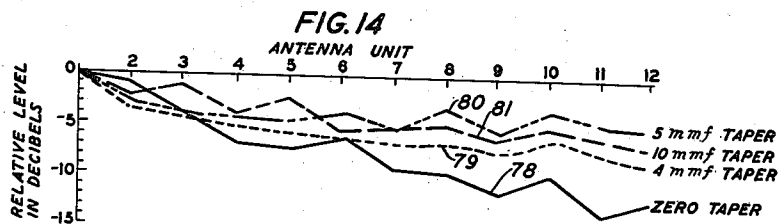
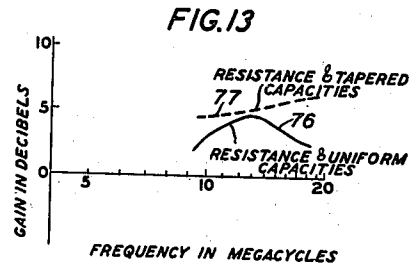
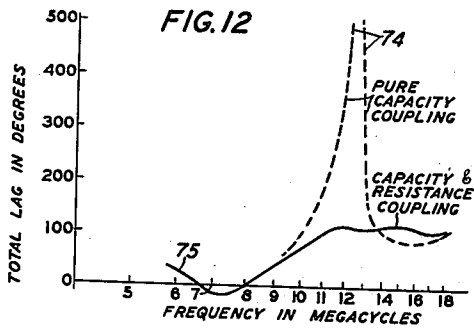
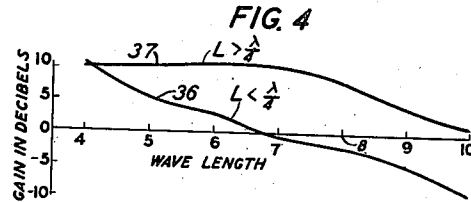
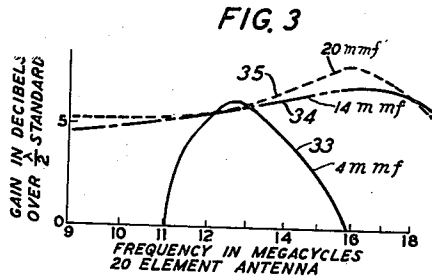
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2,236,393

DIRECTIONAL ANTENNA

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DIRECTIONAL ANTENNA

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FIG. 16

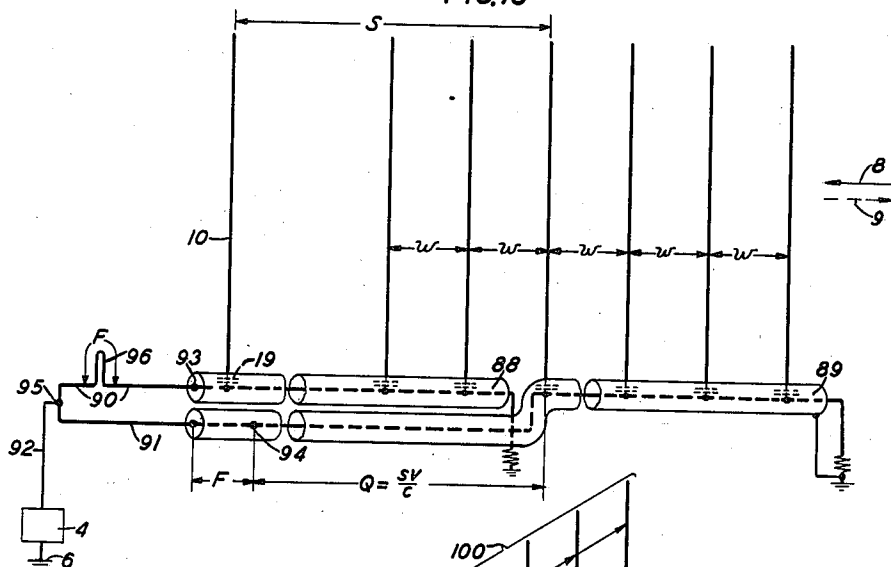
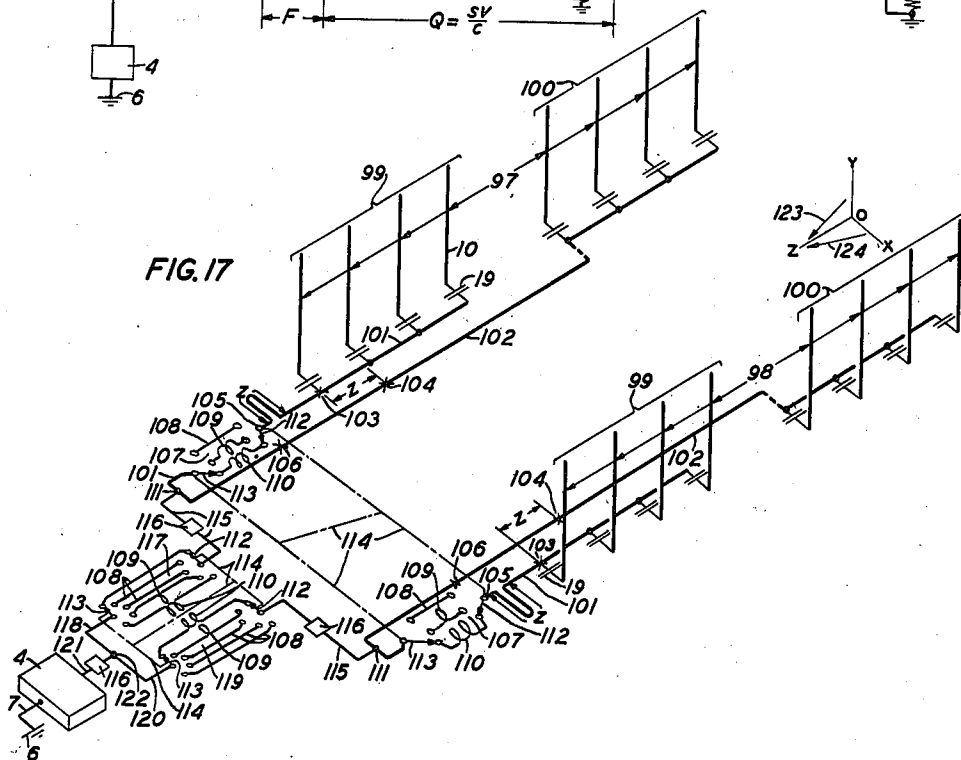


FIG. 17



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UNITED STATES PATENT OFFICE

2,236,393

DIRECTIONAL ANTENNA

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Application March 1, 1939, Serial No. 259,098

10 Claims. (Cl. 250—11)

This invention relates to radio antenna systems and more particularly to short wave directional antenna systems.

It has heretofore been proposed, as disclosed in Patent 1,821,402 to H. O. Peterson, September 1, 1931, Fig. 3, to utilize for transmission and reception of short waves at different frequencies within a given operating range, an end-on antenna unit comprising a relatively large number of doublets coupled through capacitive impedances of the same value to a single antenna transmission line connected to the transmitter or receiver. The doublets are positioned parallel to each other in a vertical or horizontal plane and perpendicular to the line; and the line extends in the direction of desired radiant action. The doublets employed in such a system are ordinarily of the high impedance type, and they are coupled to the line through a high capacitive impedance in order to secure a line velocity approximately equal to that of the wave in space and to obtain a suitable directive characteristic. The high impedance coupling and the high impedance doublets, however, function to render the gain of the antenna, as compared to a standard comparison half-wave antenna, not only relatively low at the different operating frequencies but also non-uniform over the given frequency range. As used herein a "small" condenser or capacity, a "high" capacitive impedance, and a "loose" capacitive coupling are each defined as structure including a condenser having a capacity less than 10 micro-microfarads; and a "large" condenser or capacity, a "low" capacitive impedance and a "tight" capacitive coupling are each defined as structure including a condenser having a capacity greater than 10 micro-microfarads.

It is one object of this invention to render the gain of a multifrequency end-on antenna uniform over a given operating frequency range.

It is another object of this invention to render the gain of an end-on antenna unit comprising a plurality of parallel antenna elements, relatively large and, at the same time, to secure a high line velocity.

It is still another object of this invention to improve the gain-frequency characteristic of a multifrequency end-on antenna unit without unfavorably affecting the directive characteristic of the unit at any of the operating frequencies.

It is a further object of this invention to secure a vertically polarized end-on antenna subarray or unit having a directive characteristic

specially adapted for utilization in a long range multiunit steerable array.

According to one embodiment of this invention the multifrequency antenna unit comprises a plurality of radiating or absorbing vertical members, each tightly coupled through a large capacity to the inner conductor of a horizontal coaxial transmission line extending in the desired direction of radiant action and having a grounded outer conductor. Each vertical antenna member has an actual length, not including the image conductor, equal to a quarter wavelength at one operating frequency and greater than a quarter wave-length at the remaining frequencies in the operating range. This length insures a relatively uniform gain over the operating range and renders the shunt impedance at the junction of each antenna member and the transmission line inductive, whereby the line velocity retardation occasioned by the use of the tight coupling is partly compensated. At the same time, the low impedance or tight coupling renders the gain at any given frequency relatively high. Also, assuming a given number of antenna members, further compensation for the line velocity retardation is accomplished by dividing the unit into subunits, each comprising a relatively few antenna members connected to a branch line. The branch or sublines are connected directly or through phase shifters to a common line from the translation device and are so dimensioned that the currents delivered to the receiver or antenna members are properly phased to produce a maximum effect in the desired direction. By dividing or splitting the units into subunits, the shunt capacity load on the line is greatly decreased with the result that the line velocity is not substantially decreased. An improved gain-frequency characteristic and a more desirable directive characteristic may be secured by employing capacitive coupling units having non-uniform or tapered capacity values and by connecting a resistance in shunt to each coupling condenser.

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 the prior art antenna unit referred to above;

Fig. 2 illustrates one embodiment of the invention;

Figs. 3 and 4 are curves and Fig. 5 a directive

diagram which are used in explaining the operation of the system of Fig. 2;

Figs. 6 and 7 illustrate transmission line systems constructed in accordance with the invention;

Fig. 8 illustrates a cage antenna element which may be used in the system of Fig. 2;

Figs. 9, 10 and 11 each illustrate a coupling arrangement which may be substituted for the coupling arrangement included in the system of Fig. 2;

Figs. 12, 13, 14 and 15 are curves used in explaining the results obtained with the coupling units illustrated by Figs. 9, 10 and 11;

Fig. 16 illustrates another embodiment of the invention comprising a comb-shaped antenna unit; and

Fig. 17 illustrates a steerable array in which the antenna unit of the invention is utilized.

Referring to the prior art system illustrated by Fig. 1, reference numerals 1 designate linear vertical antenna members which are spaced a small fraction of a wave-length and are connected through separate coupling condensers 2 to the transmission line conductor 3. Reference numeral 4 designates a translation device, such as a transmitter or receiver, and numeral 5 denotes a terminating impedance for rendering the system unidirectional. One terminal of the translation device 4 and one terminal of the terminating impedance 5 are connected to the ground 6 through a wire 7. The several antenna members 1 and associated line conductor 3 constitute an antenna unit which is positioned in the vertical plane containing the desired direction 8 of reception or the desired direction 9 of transmission. The condensers 2 have the same high impedance or low capacity as, for example, 3 micro-microfarads, and the antenna members each have a length L shorter than a quarter wave-length.

Referring to Fig. 2, reference numerals 10 designate linear antenna members spaced approximately one-fifth of a wave-length and arranged in four subunits or panels, 11, 12, 13 and 14, which are spaced a distance S in the direction 8 or 9 and are connected, respectively, to the branch line conductors 15, 16, 17 and 18. The members 10 each have a length L equal to a quarter wave-length at one of the operating frequencies and greater than a quarter wave-length at the remaining frequencies in the band, and these members are connected to the branch line conductors through separate condensers 19 which have the same low impedance or high capacity as, for example, a capacity greater than 10 micro-microfarads. The lines 16, 17 and 18 are, respectively, longer than line 15 by the line lengths designated 20, 21 and 22, the portions of the line conductors represented by the broken lines each having a negligible length. In actual practice these negligible line portions are not ordinarily utilized and they are shown here merely in order to illustrate clearly the principal features of the transmission line system. Branch lines 15, 16, 17 and 18 are connected through line sections or conductors 23 which have equal lengths and through the main line conductor 24 to the translation device 4. When the antenna comprising the four subunits or sections is employed as the unit antenna in a multiunit steerable array of the type disclosed in Patent 2,041,600, H. T. Friis, May 19, 1936, a phase shifter 25 is inserted in the main line conductor 24, as will be explained in more detail in connection with Fig. 17.

Referring to Fig. 1 and Fig. 2, the operation of

these systems for receiving energy will now be discussed. In the system of Fig. 1 wave energy incoming from the general direction 8 is induced in antenna members 1 and transferred through the coupling condensers 2 to the line 3 and the receiver 4. Because of the high impedance of each coupling condenser 2 and the length of each absorbing member 1, the line velocity nearly equals the velocity of the wave in space notwithstanding the fact that a relatively large number of capacity paths or antenna members, as for example 12, are connected across the line. As a result, in the case of wave energy traveling in the aforementioned direction 8, the absorbed components arrive substantially in phase at the receiver. In other words, the cooperative relation among the component parts of the system is such that the direction of maximum reception is aligned substantially with the direction 8 of the desired incoming wave.

In the system of Fig. 2, the energies are received by the members 10 and are transferred through the low impedance coupling condensers 19 to the branch lines 15, 16, 17 and 18. The wave components are then conveyed by these branch lines to the points 26, 27, 28 and 29, then conducted by the equal length line sections 23 to the main line 24 and receiver 4. Considering any of the subunits 11, 12, 13 and 14, each of the three shunt paths comprising the antenna member 10 and associated condenser 19 across the branch line is of relatively low impedance. The wave velocity V, however, on each branch line nearly equals the wave space velocity C since only a relatively few shunt paths are connected across each branch line. Hence, the energies absorbed by the three antenna members 10 constituting subunit 11 arrive substantially in phase at point 26. Similarly, in the case of subunits 12, 13 and 14 the energies arrive in phase at points 30, 31 and 32, respectively. Inasmuch as the members 10 are spaced in the path or general direction 8 of propagation or radiant action, at any given instant the phase of the energy or current at point 30 is advanced with respect to that at point 26 an amount proportional to the spacing S, along path 8, between these points; and the currents at points 31 and 32 are each advanced a like amount with respect to those at points 30 and 31, respectively. Consequently, in order to secure, for the direction 8, in-phase currents at the points 26, 27, 28 and 29, the branch lines 16, 17 and 18 are made equal in length, respectively, to

$$M + \frac{SV}{C}, M + \frac{2SV}{C}$$

and

$$M + \frac{3SV}{C}$$

where M is the length of the branch line 15 and also the length of each subunit.

While it is recognized that, in practice, the vertical plane direction of the incoming vertically polarized wave from a distant station is seldom horizontal and usually makes a varying angle with the horizontal, and while exact phase addition occurs only for the particular chosen direction of extension, namely, horizontal, of the branch line associated with the members constituting a unit or subunit as, for example, branch line 15 in subunit 11 of Fig. 2, it is not feasible to construct and use a subunit, similar to subunit 11, whose branch line may be repositioned or steered, mechanically, for alignment with any one

of the many possible vertical plane wave directions; and it is not economical to employ complete electrical steering, that is, to use an individual phase shifter and an individual properly dimensioned transmission line with each member 10 in the subunit. In fact, it is not necessary, as will be explained in connection with Fig. 17, to steer the space factor directional characteristic of the subunit 11, since several subunits may be positioned in an end-on or alignment formation which may be economically made electrically steerable whereby a satisfactory response for any incoming direction in the vertical plane may be secured. Hence, in practice, the units are preferably constructed or positioned so that the associated transmission lines and the longitudinal dimension extend horizontally, as illustrated by Fig. 2.

Referring now to Figs. 3 and 4, Fig. 3 illustrates the difference in gain obtained, in actual practice, using different values of coupling capacity with antenna members of the same length or impedance, and Fig. 4 illustrates the difference in gain actually realized using antenna members of different length and coupling condensers of the same capacity. More specifically, the curve 33 in Fig. 3 illustrates a gain-frequency characteristic obtained with a high impedance or loose coupling of 4 micro-microfarads, and numerals 34 and 35 designate the gain-frequency curves obtained using, respectively, a low impedance coupling of 14 micro-microfarads and 20 micro-microfarads. It will be noted that the low impedance or high capacity coupling, such as utilized in applicants' embodiment illustrated by Fig. 2 produced not only a flatter gain-frequency curve but also, with the exception of a few frequencies at the center of the range, produced a much higher gain at each frequency and, at the few frequencies just mentioned, substantially the same gain, as compared to that achieved using the 4 micro-microfarad coupling of the system of Fig. 1. At frequencies below 11 and above 16 megacycles no gain over the half-wave standard reference antenna was obtained when the high impedance 4 micro-microfarad condensers were employed. In Fig. 4 the reference numerals 36 and 37 illustrate the gain-frequency curves actually obtained, respectively, when antenna members each having a length, as in the system of Fig. 1, smaller than a quarter wave-length and, as in the system of Fig. 2, greater than a quarter wave-length, substantially. It will be observed that the low impedance elements produced a flatter gain-frequency characteristic and a greater gain at all wave-lengths within the range. Above seven wave-lengths, the high impedance elements produced no gain over the half-wave standard antenna. Consequently, as previously stated, the gain of the prior art system is low compared to the gain of applicants' system at substantially all the frequencies within the given operating range and the gain-frequency characteristic is considerably less uniform than that of applicants' system. This is partially due to the fact that in the system of Fig. 1 the high impedance of the coupling condensers 2 and the high impedance of the antenna members 1 effectively prevent a large transfer of energy between the line 3 and the members 1, whereas in the system of Fig. 2 the low impedance condensers 19 and the low impedance antenna members 10 permit a large transfer.

Referring to Fig. 5, the numeral 38 designates the movable end-on space factor lobe

which, as explained in the above-mentioned Friis patent, is steered over the lobe 39 or 40 of a unit antenna. It will be noted that a sharp unit lobe 39, shown by a broken line, provides a small steering range P whereas a large range R is obtained with the wide or blunt directive unit lobe 40. Referring again to Fig. 1, while increasing the lengths of members 1 and the capacity of each of condensers 2 would increase the gain of the system, it would also, in view of the large number of antenna members connected to the same line, greatly reduce the line velocity and consequently produce a relatively sharp directive lobe, such as that denoted by numeral 39. In applicants' system a maximum gain and a relatively flat gain-frequency characteristic are obtained and in addition, a high line velocity and an effective subunit directive lobe having a vertical plane width suitable for steering purposes, as illustrated by lobe 40, are achieved.

Fig. 6 illustrates a two-element antenna-counterpoise system which may be used in any plane without change and a simple transmission line arrangement for securing at the receiver in-phase currents from the two antenna members and in-phase currents from the two counterpoise members. Reference numerals 41 designate linear antenna members and numerals 42 linear counterpoise members which are structurally identical. Numerals 43 and 44 denote conductors of one branch line 45 and numerals 46 and 47 designate the conductors of another branch line 48, which branch lines are connected at points 49 to a common main line 50 associated with the translation device 4.

In operation, energies induced in the two antenna members 41 by an incoming wave having a direction 8 arrive at points 51 and 52 in phase, and in phase at the point 49 which is the junction point for conductors 45 and 46. As indicated by the following equations, the dimensions A and B shown on this figure are each a function of the known line velocity V and known space velocity C.

$$(S-2A) = \frac{SV}{C} \quad (1)$$

where S represents the distance between the elements 41,

$$A = \frac{S(C-V)}{2C} \quad (2)$$

$$B = \frac{S(C+V)}{2C} \quad (3)$$

$$\frac{A}{B} = \frac{C-V}{C+V} \quad (4)$$

Similarly, energies absorbed by the two counterpoise members 42 arrive in phase at points 53 and 54, and in phase at the point 49 which is the junction point of conductors 45 and 47. The energies at the two corresponding points 49, however, are, as is well understood, opposite in phase with respect to device 4.

Fig. 7 illustrates an economical transmission system for securing in-phase currents in a unit comprising an even plurality of antenna members. Referring to this figure, reference numerals 55 and 56 designate two element systems which are separated by a distance D and each of which is similar to the system of Fig. 6. The numeral 57 denotes the in-phase point for the system 55 and numeral 58, the in-phase point for the system 56 when a wave having the direc-

tion 8 is received, the energies at these points being out of phase an amount corresponding to the distance N. Reference numerals 59 and 60 designate branch line conductors which are connected to the main line 61 at point 62. The energies at points 57 and 58 are caused to arrive in phase at point 62 and hence to arrive in phase at the receiver 4 by making the length of line 59 equal to T+G and the length of line 60 equal to T+H where the ratio

$$\frac{G}{H} \text{ equals } \frac{C-V}{C+V}$$

The single conductor antenna members employed in the system of Figs. 2 and 7 and the single conductor antenna and counterpoise members 41 and 42 used in the system of Fig. 7 may, if desired, be replaced by the cage antenna illustrated by Fig. 8. Referring to this figure, reference numerals 70 denote linear conductors which are supported by the rings 71, these rings being formed of conductive or insulating material. The conductors at the bottom preferably converge and their common extremity 72 is connected to the coupling condenser 19. The chief advantages of the cage antenna of Fig. 8 over the single wire antenna member 10 used in Fig. 1 are a broader frequency range, a sharper maximum directive lobe for the unit, and a lower antenna input impedance.

Applicants have also discovered that additional advantages may be secured by substituting any of the coupling arrangements illustrated by Figs. 9, 10 and 11 in place of the equipment included between the lines XX and YY in Fig. 2. Referring to Fig. 9, the coupling unit comprises a high capacity 19 which is shunted by a resistance 73 of relatively large value. In practice a resistance having a value of 2000 ohms has been found to be satisfactory. In the arrangements of Figs. 10 and 11 the coupler comprises a low impedance condenser-resistance combination but the capacity of the condensers is graded or tapered from a relatively high value at the terminating impedance end of the antenna unit to a lower capacity value at the end of the antenna unit adjacent the translation device 4. In the system of Fig. 10 the couplers are divided into groups of three, each group comprising condensers of the same capacity and resistance of the same value and the groups having a capacity difference of 5 micro-microfarads. In the system of Fig. 11 the capacities of the condenser 19 are uniformly graded in steps of 2 micro-microfarads. If desired, the tapering may be steep, that is, greater than 5 micro-microfarads or gradual, as for example, 1 micro-microfarad.

Referring now to the curves of Figs. 12 and 13, the advantages produced in an actual test by utilizing the arrangements of Figs. 9, 10 and 11, will be discussed. The broken line curve 74 of Fig. 12 illustrates the lag or decrease in line velocity, from the ideal or desired space velocity, produced at the different operating frequencies by couplers each consisting of a condenser having a high capacity, as used in the system of Fig. 2; and the full line curve 75 illustrates the lag produced when the condensers mentioned above are each shunted by a resistance as illustrated by Fig. 9, the number of antenna units being the same in both cases. It will be noted that the resistance produces a more uniform or flatter lag-frequency characteristic and functions to eliminate the resonance effect or infinite lag obtained at the 12 megacycle frequency when the

pure capacity coupling arrangement was utilized. Moreover, the lag obtained with the resistance-capacity combination was, generally considered, less than that obtained with the pure capacity couplers, and at certain frequencies zero lag was obtained. The full line curve 76 of Fig. 13 illustrates the gain-frequency characteristic obtained utilizing a condenser-resistance coupling system in which the condensers have the same capacity; and the broken line curve 77 represents the gain-frequency characteristic secured with a condenser-resistance coupling arrangement comprising condensers graded as illustrated by Fig. 10. In the actual test a high gain and a more uniform characteristic was obtained, as shown by these curves, with a tapered or graded coupling arrangement.

The directive characteristic of the array is determined in part by the amplitude relation of the currents in the antenna members and, in general, the most desirable characteristic is obtained when the antenna currents are equal. If, as in the subunit 11 of the system of Fig. 2, the coupling condensers have the same capacity value, the antenna currents will be unequal since the impedances between the translation device 4 and the three antenna members are different from each other. Thus, considering subunit 11 as a transmitting system, a large amount of energy is supplied at the transmitter to the first or near-end antenna member but only a relatively small amount reaches the far-end member 10 inasmuch as the intervening antenna member radiates a portion of the energy. Conversely, in the case of receiving, while the members 10 absorb equal amounts of energy from the incoming wave, substantially less energy arrives at the receiver from the far-end member than arrives from the near-end element because of the impedance difference of the two paths traversed. Properly tapering or grading the capacity values of the couplers results in a more uniform antenna amplitude distribution, as shown by the curves of Fig. 14.

Referring to Figs. 14 and 15 the full line curve 78 illustrates a measured current distribution for a twelve-member unit comprising condenser-resistance couplers having the same capacity value or zero taper and the broken line curves 79, 80 and 81 illustrate the distribution obtained with different degrees of capacity grading or tapering, curves 79, 80 and 81 representing, respectively, the distribution secured with a small taper, a medium taper, and a steep taper. For the particular system tested, the medium taper of 5 micro-microfarads produced the best or most uniform distribution. An ideal equal current distribution produces the satisfactory horizontal directive characteristic illustrated by the broken line curve 82 of Fig. 15 whereas an unequal distribution obtained with zero taper produces the somewhat inferior characteristic illustrated by curve 83. More specifically, considering the suitable characteristic 82, the unequal distribution causes the major lobe 84 to become too broad, the nulls 85 to disappear, the minor lobe 86 to increase, and the back effect 87 to increase; and all these effects are highly undesirable. The curves for the three tapered arrangements of Fig. 14 are not shown on Fig. 15 but if shown would fall between the two curves 82 and 83 of Fig. 15.

Referring to Fig. 16, a particularly useful and economical array constructed in accordance with the invention and designed to receive or transmit vertical polarized waves is illustrated. This

array, hereinafter called the "comb" array, comprises two groups of antenna members connected to the device 4 by means of the two low impedance coaxial branch lines 88 and 89. The antenna members are spaced a distance W and the coaxial lines are connected through separate conductors 90 and 91 to the main line conductor 92. The coupling condensers 19 are positioned inside of the outer conductors of the coaxial lines.

The system of Fig. 16 functions in substantially the same manner as explained in connection with Fig. 2. Briefly, the energies arrive at points 93 and 94 in phase since the distance Q equals

$$\frac{SV}{C}$$

In order to obtain in-phase energies at the receiver or at point 95, line 90 is made equal in length to line 91 by inserting a line section 96 having a proper length F in conductor 90. Obviously, the comb array of Fig. 16 may be longer and may contain more than two groups and, as in the system of Fig. 2, it may be used for transmitting as well as for receiving.

Referring to Fig. 17, a broadside array comprising two end-on subarrays 97 and 98 is illustrated, each end-on or alignment subarray comprising two subunits 99 and 100 each constructed in accordance with the invention. Each subarray 97 and 98 is arranged for vertical plane steering and the broadside array is arranged for a horizontal plane in the manner disclosed in co-pending joint application of C. B. H. Feldman and H. T. Friis, filed October 12, 1938, Serial No. 234,562, assigned to applicants' assignee. As explained in connection with Fig. 16, in each subarray, the line conductors 101 and 102 which are associated, respectively, with units 99 and 100 are so dimensioned that the in-phase energies at points 103 and 104 travel over equal length paths so as to arrive in phase at points 105 and 106. Reference numerals 107 designate adjustable line type delay networks or phase shifters one of which is included in each of the lines 101, each network comprising the line sections or paths 108, 109 and 110 which have different lengths. For example, the length of paths 109 and 110 may be respectively two and three times the length of path 108. In each subarray, when the movable contacts 112 and 113 are connected to line section 108, the path from point 105 through section 108 to point 111 is equal to the length of the path from point 106 on conductor 102 to the point 111. As explained in the Feldman-Friis application, the four contacts 112 and 113 in the two phase shifters 107 are preferably uncontrolled, as indicated by the broken lines 114, whereby the same amount of delay may be simultaneously inserted in the two lines 101.

The line 115 from the subarray 97 is connected through an impedance matching device 116 and phase shifter 117 to line 118, and the line 115 from subarray 98 is similarly connected through an impedance matching device 116 and a phase shifter 119 to line 120. An impedance matching device 116 is inserted in line 121 between the junction point 122 and the device 4. Each of the phase shifters 117 and 119 comprises three equal length sections 108, a longer section 109 and a still longer path 110. The arrangement is such that upon manipulation of the four uncontrolled contacts 112 and 113 the phase shift or delay introduced by the phase shifter 117 and the phase shifter 119 may be rendered substantially equal to zero or a greater delay, in either

of the two different amounts, may be introduced in one of the lines 118 or 120 without introducing delay in the other line.

As explained in the above-mentioned joint application of C. B. H. Feldman and H. T. Friis, the maximum directive lobe of the array may be steered or adjusted in the vertical plane by proper adjustment of the two phase shifters 107 and steered in the horizontal or azimuthal plane by suitable adjusting phase shifters 117 and 119 whereby the principal axis of the maximum lobe may be aligned with the actual direction of a desired incoming wave. In other words, it may be aligned with a wave having a direction the projections of which, on the vertical plane YOZ and the horizontal plane XOZ, Fig. 17, are illustrated respectively by the arrows 123 and 124. Thus antenna units constructed in accordance with applicants' invention may be readily employed in steerable transmitting or receiving systems. Moreover, as explained in connection with Figs. 5 and 15, the directive lobe of each of subunits 99 and 100 is admirably suited for use in such systems since it provides a suitable steering range. In Fig. 5, numeral 40 designates the directive lobe of subunit 99 or 100, in either subarray 97 or 98. Numeral 38 denotes the space factor lobe of the corresponding end-on subarray 97 or 98 and numeral 125 denotes the space factor lobe of the two subarrays, that is, the broadside space factor.

Although the invention has been explained in connection with certain embodiments, it is to be understood that it is not to be limited to these embodiments since other apparatus and equipment may be satisfactorily employed in practicing the invention.

What is claimed is:

1. In combination, an antenna unit comprising a plurality of antenna members spaced on the general path of desired radiant action, substantially, a transmission line extending along said path, a plurality of low impedance condensers, each member being coupled to the line by a separate condenser, and a translation device connected to an intermediate point on said line, the difference in the lengths of the paths connecting said device to said members being related to the spacing between said members and the wave velocity on said line.

2. In combination, an antenna comprising a plurality of sections each comprising a plurality of radiating or absorbing members, a section transmission line extending in the general direction of radiant action, a plurality of large capacity condensers, each member being connected to its line through a different condenser and a translation connected to one set of corresponding terminals of the section lines, the paths connecting said device to said terminals of adjacent section lines having a difference in length related to the spacing between the last-mentioned terminals and the wave velocity on said line.

3. A combination in accordance with claim 2, and a plurality of resistances each connected in shunt with a different condenser.

4. In combination, an antenna unit comprising a plurality of sections each comprising a plurality of antenna members spaced horizontally along the general path of desired radiant action, substantially, a transmission line in each section extending along said path, a plurality of large condensers, each antenna member being coupled to its section line through a separate condenser and the capacities of said condensers being ta-

pered or graded along said unit, and a translation device connected to one set of corresponding terminals of the section lines, the paths connecting said device to said terminals of adjacent section lines having a difference in length related to the spacing between the last-mentioned terminals and the wave velocity on said lines.

5. In combination, an antenna unit comprising a plurality of sections each comprising a plurality of antenna members spaced along the path of desired radiant action, substantially a transmission line in each section extending along said path, a plurality of large condensers, each member being coupled to its section line through a separate condenser, the condensers in each section having the same capacity and an individual capacity differing from the individual capacity of the condensers in the adjacent sections, and a translation device connected to one set of corresponding terminals of said section lines, the paths connecting said device to adjacent section lines having a difference related to the spacing between the fore-mentioned terminals of said lines and the wave velocity on said lines.

6. A system for communication between two stations comprising at one station a directive antenna unit, said unit comprising at least two sets or panels of parallel antenna members spaced along a path of radio propagation connecting said station and the cooperating station, at least two panel transmission line conductors coinciding with and spaced along said path, one set of antenna members being coupled to one panel line and another set to the other panel line, a translation device, and paths of substantially the same conductivity connecting said device to corresponding points on said panel lines, the path connecting the device and the panel positioned nearer the cooperating station being longer than the path connecting the device to the other panel by an amount proportional to the space between corresponding members in said panels and the velocity of the wave on said paths.

7. In combination, an antenna unit comprising a plurality of sections arranged in a line extending in the general direction of desired radiant action and each comprising a relatively few parallel low impedance antenna members, a section line conductor and separate low impedance condensers for coupling each member to the associated section line, a plurality of main line conductors connecting said device to corresponding terminals of said section line conductors, said main line conductors having a difference in

length related to the spacing between corresponding members in said sections and the wave velocity on said conductors.

8. In combination, an antenna unit comprising a plurality of sections arranged in a line extending horizontally and in the general direction of desired radiant action and each comprising a relatively few parallel low impedance antenna members, a linear section line conductor and a separate low impedance condenser coupling each member to the associated section line conductor, a translation device, and a plurality of main line conductors connecting said device to corresponding terminals of the section line conductors, the main line conductors connected to adjacent sections having a difference in length equal to

$$\frac{SV}{C}$$

where S is the spacing between corresponding points in said adjacent sections and V and C are the wave velocities, respectively, on the main line conductors and in space.

9. In combination, an antenna unit comprising two sections spaced along the path of desired radiant action, substantially, each section comprising a plurality of vertical members spaced along said path and a coaxial section transmission line comprising an inner conductor and an outer conductor, a plurality of low impedance condensers each positioned within said outer conductor and each coupling a different member to its section line, a translation device, and main line conductors connecting said device to corresponding terminals of said coaxial lines and having a difference in length directly proportional to the spacing between said corresponding terminals and inversely proportional to the wave velocity on said conductors.

10. In combination, a plurality of antenna sections each comprising a plurality of relatively low impedance antenna members, a section transmission line extending in a general direction of radiant action, a plurality of low impedance condensers, each member being coupled to its section line through a different condenser, a translation device, a plurality of main lines connecting said device to corresponding terminals of the section lines sections, said main lines having a difference in length related to the spacing of said corresponding terminals on the path of desired wave propagation, and a phase shifter included in one of said main lines.

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