March 7, 1939. P. S. CARTER 2,149,726

ANTENNA SYSTEM

Original Filed April 12, 1935 4 Sheets-Sheet 1

Fig. 1

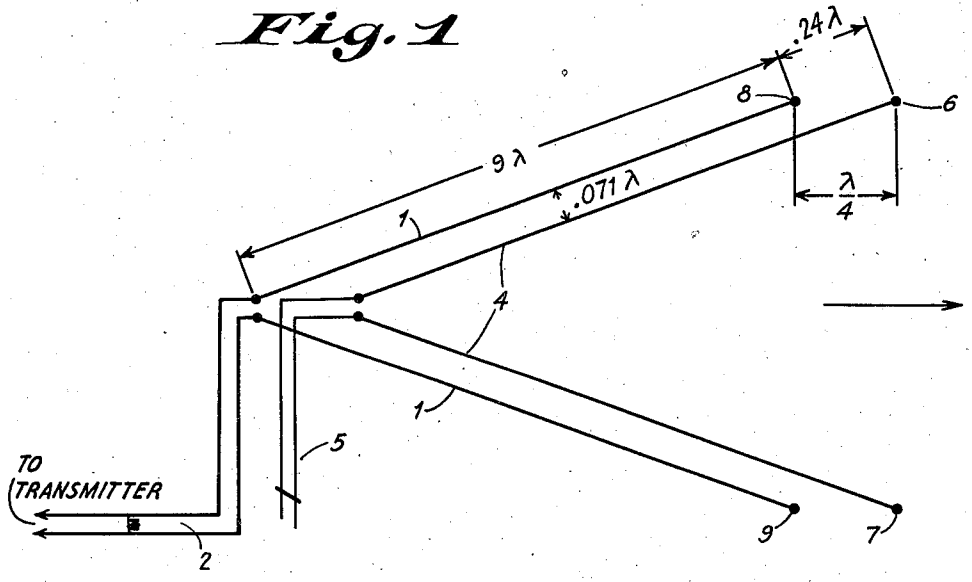


Fig. 2

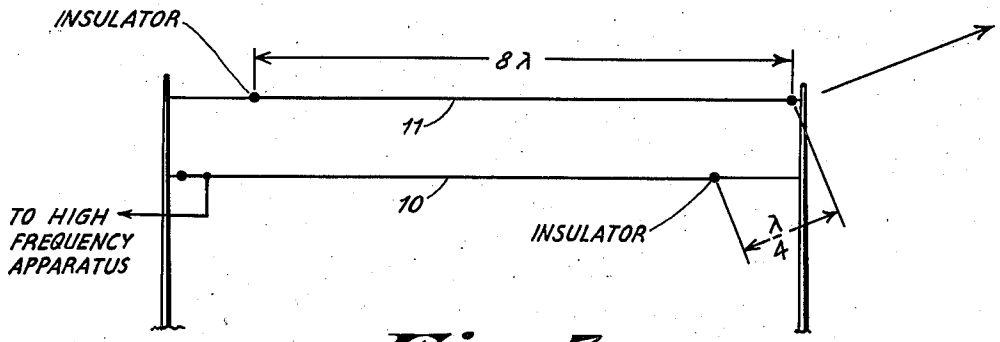
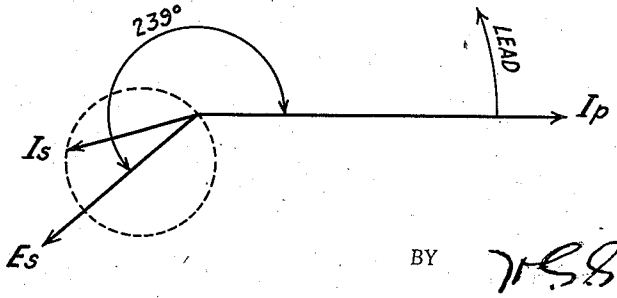


Fig. 7



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Fig. 3

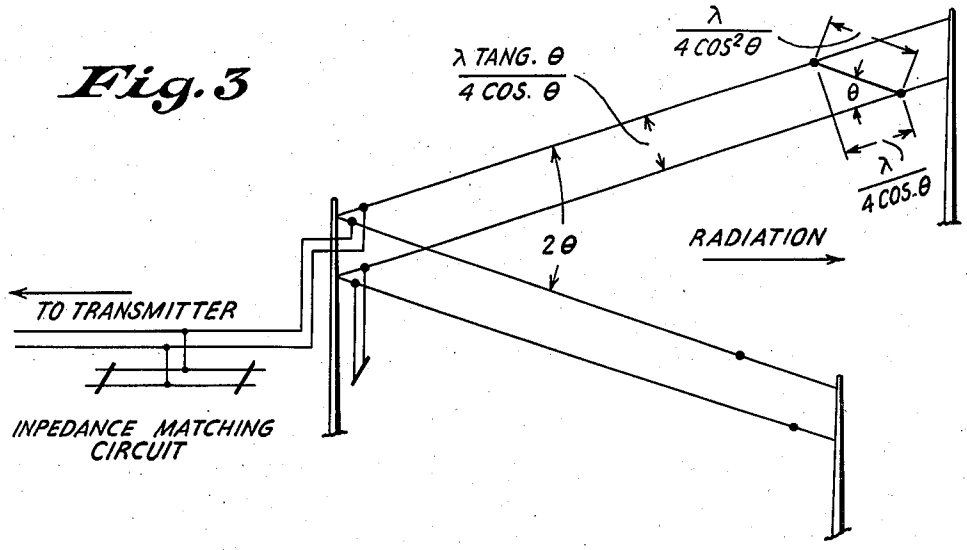
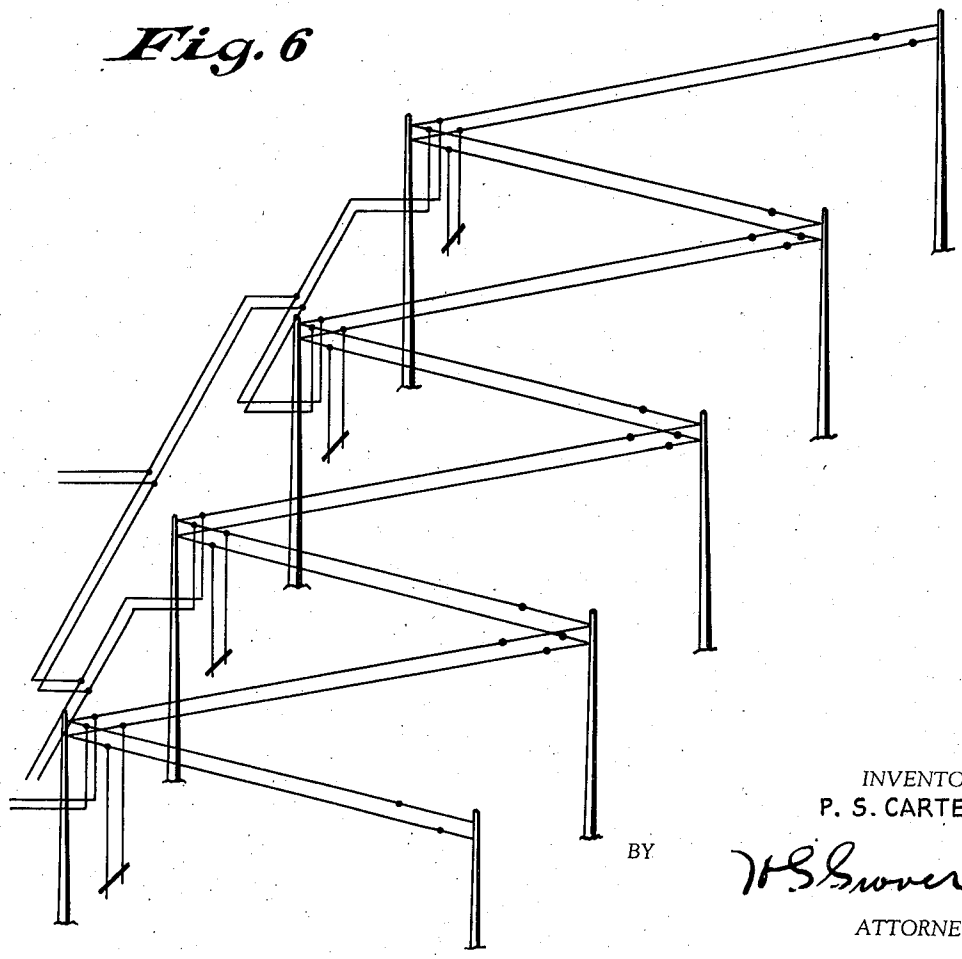


Fig. 6



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Fig. 4

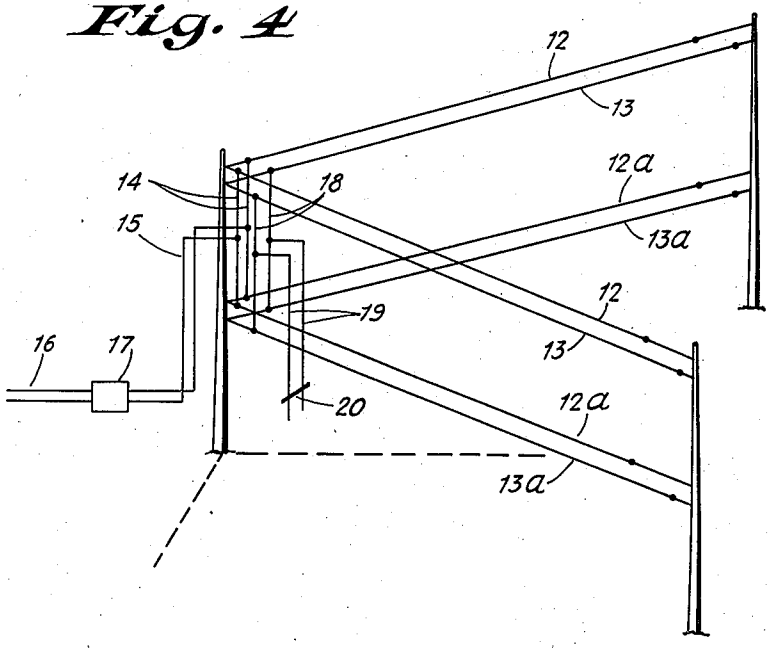
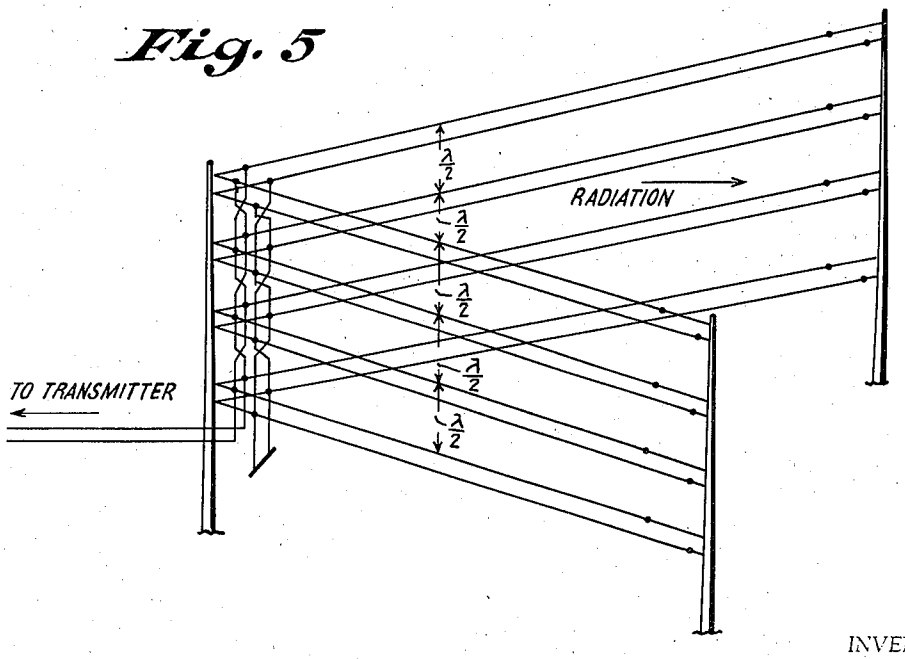


Fig. 5



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Fig. 8

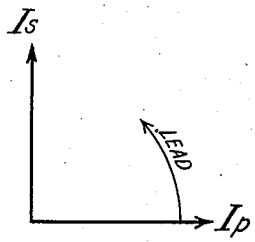


Fig. 9

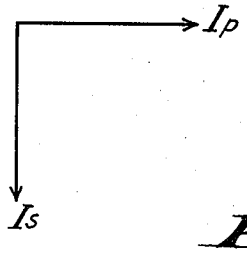


Fig. 10

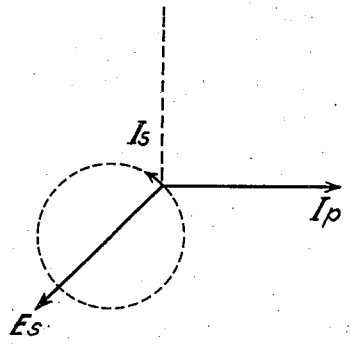


Fig. 11

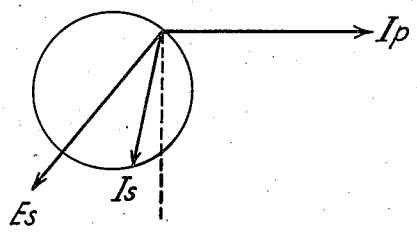
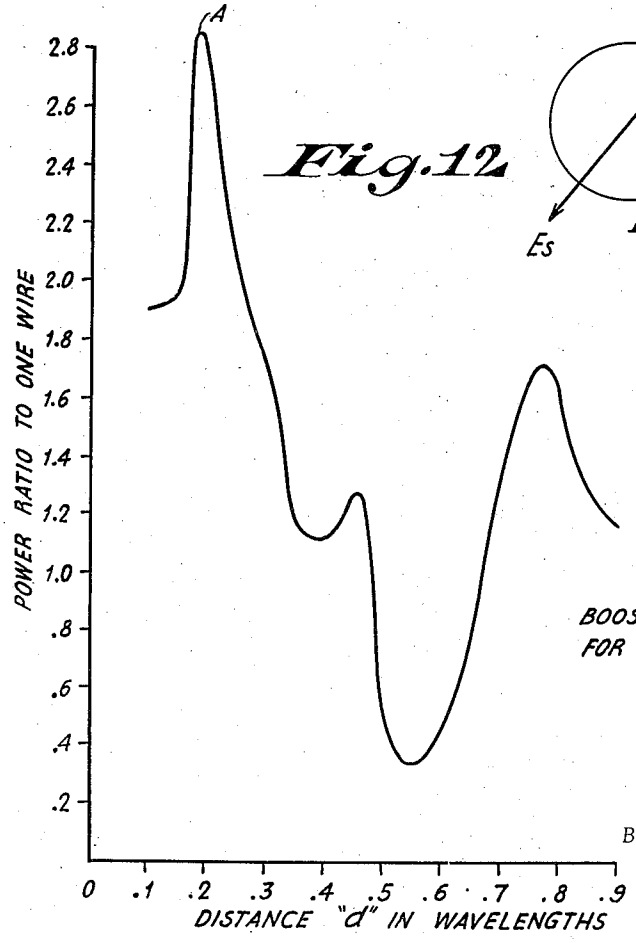


Fig. 12



BOOSTER TUNED NON-REACTIVE FOR THIS CURVE

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Patented Mar. 7, 1939 2,149,726

UNITED STATES PATENT OFFICE

2,149,726

ANTENNA SYSTEM

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Application April 12, 1935, Serial No. 15,958
Renewed April 23, 1938

20 Claims. (Cl. 250—11)

This invention relates to undirectional directive antennae.

It is well known that a unidirectional characteristic can be obtained in an antenna system by providing a reflector unit a certain distance behind the main or primary unit, the reflector being energized through a transmission line, or else left floating or unenergized. It has been found when utilizing certain types of antennae under particular conditions that the voltage induced in the reflector unit has such a phase relation with respect to the current in the primary unit that an adjustment giving efficient reflector action is impossible.

An object of the present invention is to overcome the difficulties hitherto experienced and to provide, among other things, a highly efficient unidirectional system; and this is accomplished by employing a floating or unenergized booster unit whose far end is ahead of the far end of the energized primary unit in the line of transmission.

One advantage of the present invention over many known types of antennae is that there are required fewer supporting structures for the system; consequently there is an appreciable saving in the cost of construction. This is especially the case when V-type antennae are used in accordance with the present invention, since one set of supports is then employed for both the booster and primary units instead of two sets heretofore required for a unidirectional system.

It should be noted that the invention applies to receiving as well as to transmitting antennae, the primary unit in both cases being the one to which the high frequency apparatus is coupled, the other unit being the unenergized or floating booster which has its far end or ends ahead of the primary unit in the direction of communication. In a receiving system, the receiver is connected to the primary unit and the far end of the booster is nearest the transmitting station.

A better understanding of the invention may be had by referring to the following detailed description which is accompanied by drawings, wherein:

Figs. 1 to 6, inclusive, illustrate, diagrammatically, different embodiments of the invention; Figs. 7 to 11, inclusive, are vector diagrams; and Fig. 12 a graph, explanatory of the invention.

Referring to Fig. 1, there is shown a transmitting antenna system comprising a primary unit 1 to which is connected high frequency apparatus over transmission line 2, and a booster unit 4 whose far ends 6, 7 are ahead of the far ends 8, 9 of the primary unit in the direction of the line of transmission shown by the arrow. Booster unit 4 is unenergized or floating and its adjacent ends are connected to a tuning element 5 comprising a pair of parallel wires with an adjustable slider. The primary unit 1 and the booster 4 are in the same horizontal plane and each unit comprises a V-type of antenna consisting of two wires which are long with respect to the working wave length and angularly disposed with respect to one another. Reference is herein made to my United States Patent No. 1,974,387, granted September 18, 1934, for a detailed description of the V-type antenna and the manner of obtaining the angle between the wires of the V.

In this particular embodiment, the individual wires of the V's of both primary and booster are each nine wave lengths long. It is preferred that the wires of the primary and booster be a plurality of wave lengths long but the invention is not limited in this respect to any plurality or fraction thereof, since it is applicable to any system wherein the wires are at least greater than one wave length. It should also be noted that the wires of the booster need not be of the same length as the wires of the primary unit in order to practice the invention, and that although the units of Fig. 1 are described as being in the horizontal plane, the system functions with the units in any plane.

The phase of the current in the booster 4 with respect to the current in primary unit 1 is determined chiefly by the position of the ends 6, 7 with respect to the ends 8, 9 of the primary unit. Of course, it will be appreciated that a certain amount of control of the phase of the current in the booster with respect to the current in the primary is also obtained by means of tuning element 5 and other tuning mechanisms of the system. The projection of the distance between the far ends of the booster and primary units upon the direction of transmission should have a length in the range between .2 and .35 wave length for most efficient action, and this length is determined by the mutual impedance between the primary unit and the booster. The mutual impedance between long wires in echelon may be determined by means of formulas given in an article published by me in the Proc. of the I. R. E., June, 1932, vol. 20, pp. 1004 to 1041, entitled "Circuit relations in radiating systems and applications to antenna problems". In the system of Fig. 1, a projection of 0.24 wave length was used and gave very satisfactory results. Differ-

ences in effectiveness are obtained by varying the spacing between the booster and the primary along the line of direction of radiation. As a general rule, the spacing between correspondingly located wires should be quite close, preferably between .03 and .1 wave length. Fig. 1 shows a spacing of .071 wave length.

For the system of Fig. 1, the relations of current and voltage are shown vectorially in Fig. 7, wherein I_p is the current in the primary unit 1, E_s the voltage induced in the booster unit 4 with the dimensions and spacing as given in the drawings, and I_s the current in the booster. By means of tuning, the terminus of I_s can be made to take any position on the circle shown in dotted lines. Fig. 8 shows the ideal relations between I_p and I_s for "reflector" action, and Fig. 9 the ideal condition for "booster" action. Fig. 10 shows the best phase adjustment possible for "reflector" action under the conditions of Fig. 1, and Fig. 11 for "booster" action. It will be observed from Figs. 10 and 11 that the current in the reflector is negligible for the best "reflector" adjustment while quite high for best "booster" adjustment; in other words, the secondary unit is of practically no value as a reflector. In general, the ideal phase relations for either a reflector or a booster do not result in the maximum possible gain, though they do give maximum radiation for a given current, a matter of no particular consequence. What is desired herein is maximum radiation in a given direction for a given power input, and it will be appreciated that usually the power for fixed current in the primary unit varies widely as changes are made in the secondary unit.

Fig. 2 shows an antenna in accordance with the invention system comprising a single wire primary unit 10 and a single wire unenergized booster unit 11, located above the primary in the same vertical plane and adapted to be supported by the same poles. Although the booster 11 is herein shown located above the primary, the invention is not limited to such an arrangement, since the booster may just as well be located below the primary, if desired, it being understood, of course, that the principles outlined above should be adhered to with respect to the length of the wires, the location of the far end of the booster with respect to the far end of the primary, the floating character of the booster, etc.

Fig. 12 shows a typical curve of gain versus spacing for a system of two staggered wires as shown in Fig. 2. This curve represents the case where the booster is tuned to be non-reactive and shows how very poor the floating unit acts as a reflector and the excellent results obtained when the floating unit acts as a booster. New curves may be obtained by shifting the phase of the currents in the wires by tuning the booster, so that within a range of spacing between the ends of the wires of .2 to .3 wave length excellent results are achieved. By different tuning adjustments of the booster a whole family of curves may be obtained, since the point A of the curve showing maximum gain will be shifted.

Fig. 3 shows a particularly desirable antenna system in accordance with the invention which has been successfully used in practice. The system of this figure comprises two V-antennae, one above the other, supported by the same set of structures, the booster in this case being the lower V and having wires of different length from those of the upper primary V. The angle between the wires of the V's is determined in accordance with the principles set forth in my above mentioned United States Patent No. 1,974,387. Although the formulas shown in this figure for the projection and spacing betwen the wires of the two V's have been found to give good results, they are not necessarily correct for the systems of Figs. 1 and 2.

It should be understood that the spacing between corresponding wires in the same plane throughout the figures is not very critical since the projection of the wires on the line of direction of radiation, which in Fig. 3 determines the spacing between wires, may be anywhere near one-quarter wave length and the control of the phase of the currents in the wires may be assisted by tuning elements at or near the near end of the system.

It has been found that by means of the present invention there is obtained an arrangement giving extremely low back radiation. In practice, there is obtained a difference of 35 to 40 decibels between front and back radiation.

Fig. 4 shows an arrangement of the invention wherein two booster systems are provided stacked one above the other. In this embodiment, V wires 12 and 13 comprise, respectively, the antenna and booster elements of the upper booster system, and V wires 12*a* and 13*a* the corresponding elements of the lower booster system. For connecting elements 12 and 12*a* there are employed jumper wires 14 to the center points of which is connected transmission line 15, which connects through a suitable impedance matching unit 17 and a transmission line 16 to an energy source, not shown. Additional jumper wires 18 connect together wires 13 and 13*a* and line 19, terminated by an adjustable shunt 20, connects to the center points of these jumper wires 18. It will be apparent that tuning of the booster is thus accomplished by adjusting shunt 20. The vertical spacing between the booster systems may be of any desired magnitude but should ordinarily be at least of one-half a wave length. If more than one frequency is to be used, it is preferred to employ this arrangement to that of Fig. 5, since the currents in 12 and 12*a* are in phase with each other, as well as those in 13 and 13*a* being in phase with each other, regardless of frequency. In Fig. 5, a particular spacing is used for one particular frequency in order to obtain the in-phase relationship; consequently any change in the frequency will require a change in the spacing or in the lengths of the jumper feeders.

Fig. 5 shows a system of four stacked units similar to Fig. 4 with the exception of the feeding system. In Fig. 5 the spacing between the corresponding elements of the booster systems is one-half wave length, and the vertical jumper wires are criss-crossed between elements in order to obtain correct phasing. As shown in the drawings, the transmission line is connected to the junction of the vertical jumper with the lowermost V booster system. The line section with adjustable shunt for tuning the booster is also connected in a similar manner.

Fig. 6 shows a broadside arrangement of four units placed side by side adjacent one another and facing the same direction. This arrangement, it is believed, is self-explanatory. Although each booster system or "bay" of the broadside arrangement is shown as having one unit of antenna and reflector only, it will be obvious that several of the systems may be stacked one above the other, as shown in Fig. 5, and may be placed in broadside in the same manner.

In general, the following considerations should

be followed in the practice of the invention.

(a) The wires should be longer than one wave length, preferably several or more wave lengths long with respect to the working wave.

(b) The booster should be left floating, i. e., unenergized.

(c) The far end of the booster should be ahead of the correspondingly located end of the primary unit in the direction of communication.

By the term "far end", used in the foregoing description and in the following appended claims, is meant that end of a wire which is farthest removed from the directly associated high frequency apparatus, or more specifically in the case of the booster wire, that end which is nearest the distant station with which it is desired to communicate.

It will be understood, of course, that the invention is not limited to the precise arrangements of parts shown since various modifications may be made without departing from the spirit and scope thereof.

What is claimed is:

1. A unidirectional antenna system comprising two staggered wires in the same vertical plane and located one above the other, each of said wires having a length at least as long as the length of the communication wave, high frequency apparatus connected only to that one of the wires whose far end is behind the corresponding end of the other wire in the direction of communication, said other wire being left floating.

2. A unidirectional antenna system comprising two spaced staggered wires in the same vertical plane and located one above the other, the projection of the far ends of said wires on the line of direction of communication being within the range of 0.2 to .35 wave length, each of said wires having a length at least as long as the length of the communication wave, high frequency apparatus connected only to that one of the wires whose far end is behind the corresponding end of the other wire in the direction of communication, said other wire being left floating.

3. A unidirectional antenna system comprising two parallel V antennae in the same plane, the corresponding wires of said V antennae being spaced apart a distance between 0.03 and 0.1 wave length, the projection of the far ends of the correspondingly located wires of said V antennae upon the line of direction of communication being between 0.2 and .35 wave length, a tuning element coupled to that V antenna whose far end is ahead in the direction of communication, and high frequency apparatus connected to said other V antenna, the wires of each V antenna being at least as long as one wave length.

4. A unidirectional antenna system comprising a V antenna constituted of two wires each at least one wave length long and angularly disposed with respect to the other, means for energizing said antenna at the closest adjacent ends of said wires whereby radiation is along the plane of the bisector of the angle formed by the wires, another V antenna located in a plane parallel to the plane of the wires of said first V antenna and spaced a vertical distance from said first V antenna, the far ends of the wires of said second V extending in the same direction as and lying ahead of the far ends of the wires of said first V antenna, a tuning element connected to the closest adjacent ends of the wires of said second V antenna, the projection of the far ends of correspondingly located wires of said two V antennæ upon the direction of communication being within the range of .2 to .35 wave length, said means comprising high frequency transmitting apparatus coupled only to said first V antenna.

5. A system in accordance with claim 3 characterized in this that the wires of both V antennæ are of the same length and a plurality of wave lengths long, the spacing between correspondingly located wires of the two V's being approximately 0.07 wave length, and the projection of the far ends of the wires of the V's upon the line of direction of communication being approximately one-quarter wave length.

6. A system in accordance with claim 4, characterized in this that both V antennae are of different lengths and substantially in the horizontal plane, said first V antenna being located above said second V antenna.

7. A unidirectional antenna system comprising a single wire antenna located substantially in the horizontal plane, a floating single, horizontal wire booster spaced vertically away from said first wire and located in the same vertical plane with said first wire, high frequency communication apparatus connected only to said first wire, the far end of said booster being located ahead of the far end of said antenna wire in the line of direction of communication, both of said wires being at least one wave length long.

8. A unidirectional antenna system comprising, in combination, a first pair of wires in the same horizontal plane angularly disposed with respect to each other, and a second similar pair of angularly disposed wires spaced from said first pair and having its far ends ahead of the far ends of the wires of said first pair, a tuning element coupled to said second pair of wires, and high frequency apparatus coupled only to said first pair of wires, the wires of each pair being at least as long as one wave length, one of said pairs being located above the other in such manner that the correspondingly located wires of both said pairs are in the same vertical plane.

9. A system in accordance with claim 8, characterized in this that said high frequency apparatus comprises transmitting equipment, and the wires of said two pairs are of unequal length.

10. A system in accordance with claim 8, characterized in this that said high frequency apparatus comprises receiving equipment and the wires of said two pairs are of equal length.

11. A system in accordance with claim 8, wherein there is provided a similar antenna arrangement of two pairs of wires spaced from said first system a vertical distance equal to at least one-half a wave length, the wires of said two systems being connected together by jumpers.

12. A system in accordance with claim 8, including one or more similar arrangements placed side by side adjacent one another and facing the same general direction so as to constitute the whole of a broadside antenna system.

13. A unidirectional antenna system comprising two staggered wires in the same vertical plane and located one above the other, each of said wires having a length at least as long as the length of the communication wave, high frequency apparatus connected only to that one of the wires whose far end is behind the corresponding end of the other wire in the direction of communication, said other wire being left floating, the projection of the spacing between said ends upon the direction of travel of the communication wave having a length substantially equal to one-quarter of the length of the communication wave.

14. A unidirectional antenna system comprising two parallel V antennæ in the same horizontal plane, the corresponding wires of said V antennae being spaced apart a distance between 0.03 and 0.1 wavelength, the projection of the far ends of the correspondingly located wires of said V antennæ upon the line of direction of communication being between 0.2 and .35 wavelength, a tuning element coupled to that V antenna whose far end is ahead in the direction of communication, and high frequency apparatus connected to said other V antenna, the wires of each V antenna being at least as long as one wavelength.

15. A unidirectional antenna system comprising two staggered wires of different lengths in the same vertical plane and located one above the other, each of said wires having a length at least as long as the length of the communication wave, high frequency apparatus connected only to that one of the wires whose far end is behind the corresponding end of the other wire in the direction of communication, said other wire being left floating.

16. A unidirectional antenna system comprising two staggered wires of different lengths in the same vertical plane and located one above the other, said longer wire being located below the shorter wire and having its far end extending ahead of the corresponding end of the other wire, high frequency apparatus connected only to said shorter wire, said longer wire being left floating.

17. A unidirectional antenna system comprising a single wire antenna, a parallel, floating, single wire booster spaced away from said single wire antenna, high frequency apparatus connected only to said first wire, the far end of said booster being located ahead of the far end of said antenna wire in the line of direction of communication, both of said wires being at least one wavelength long.

18. A unidirectional antenna system comprising a V antenna constituted of two wires each at least one wave length long and angularly disposed with respect to the other, means for energizing said antenna at the closest adjacent ends of said wires whereby radiation is along the plane of the bisector of the angle formed by the wires, another V antenna also at least one wave length long and located in a plane parallel to the plane of the wires of said first V antenna and spaced a vertical distance from said first V antenna, the far ends of the wires of said second V extending in the same direction as and lying ahead of the far ends of the wires of said first V antenna, a tuning element connected to the closest adjacent ends of the wires of said second V antenna, the projection of the far ends of correspondingly located wires of said two V antennae upon the direction of communication being within the range of .2 to .35 wave length, and high frequency apparatus coupled only to said first antenna.

19. A unidirectional antenna system comprising a single wire antenna located substantially in the horizontal plane, a floating, single horizontal wire booster spaced above said first wire and located in the same vertical plane, high frequency communication apparatus connected only to said first wire, the far end of said booster being located ahead of the far end of said antenna wire in the line of direction of communication, both of said wires being of the same length and at least one wave length long.

20. A unidirectional antenna system comprising two similar antenna structures located one above the other, said structures being staggered relative to one another in the direction of communication, high frequency translating apparatus connected only to that antenna structure whose far end is behind the corresponding end of the other structure in the direction of communication, said other structure being left floating.

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