

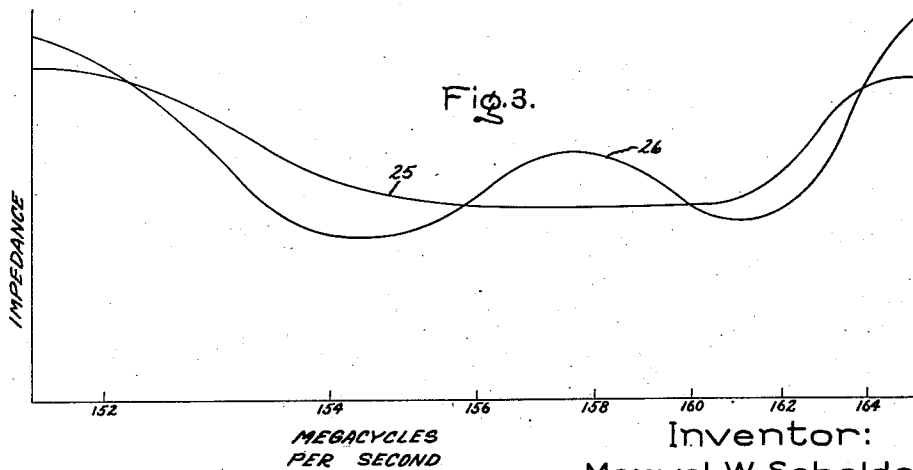
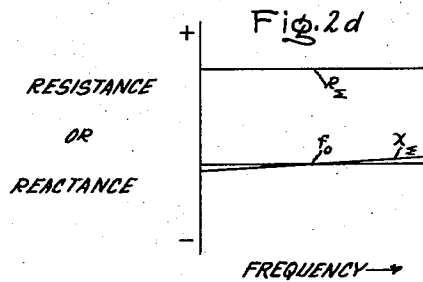
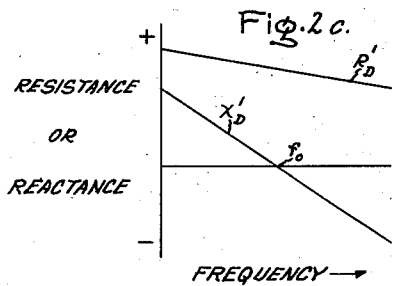
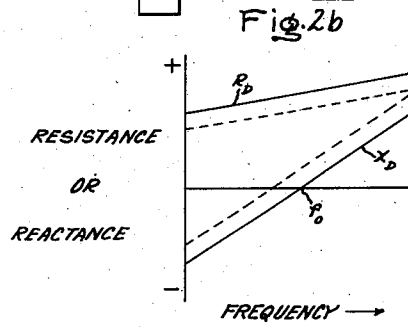
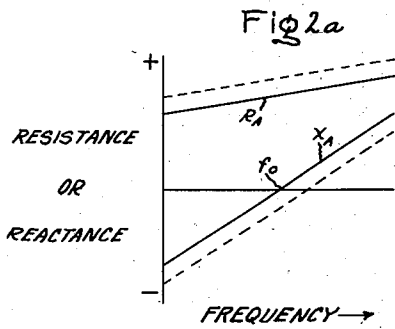
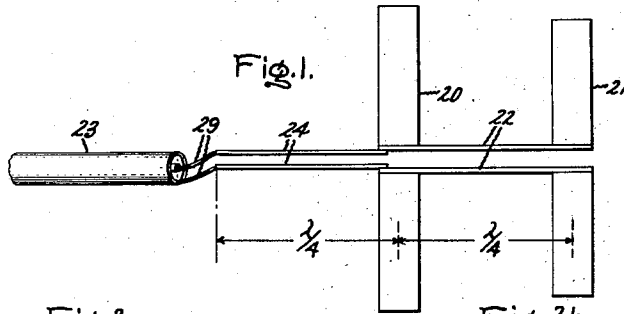
Sept. 29, 1942.

M. W. SCHELDORF
WIDE BAND ANTENNA ARRAY

2,297,329

Filed July 8, 1941

3 Sheets-Sheet 1



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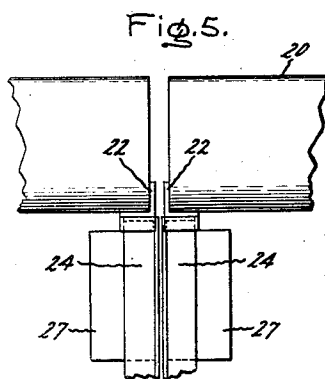
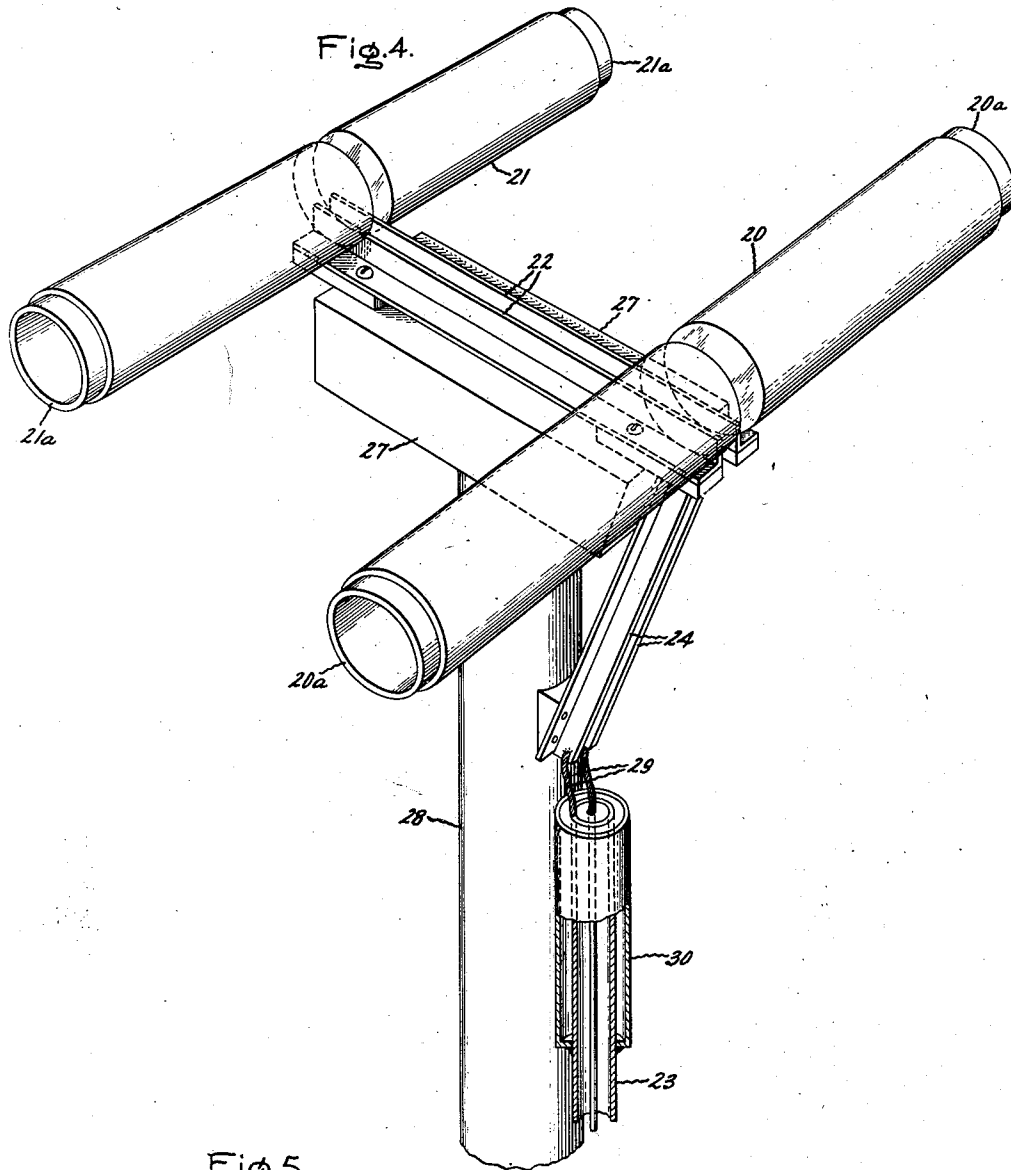
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M. W. SCHELDORF
WIDE BAND ANTENNA ARRAY

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3 Sheets-Sheet 2



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Sept. 29, 1942.

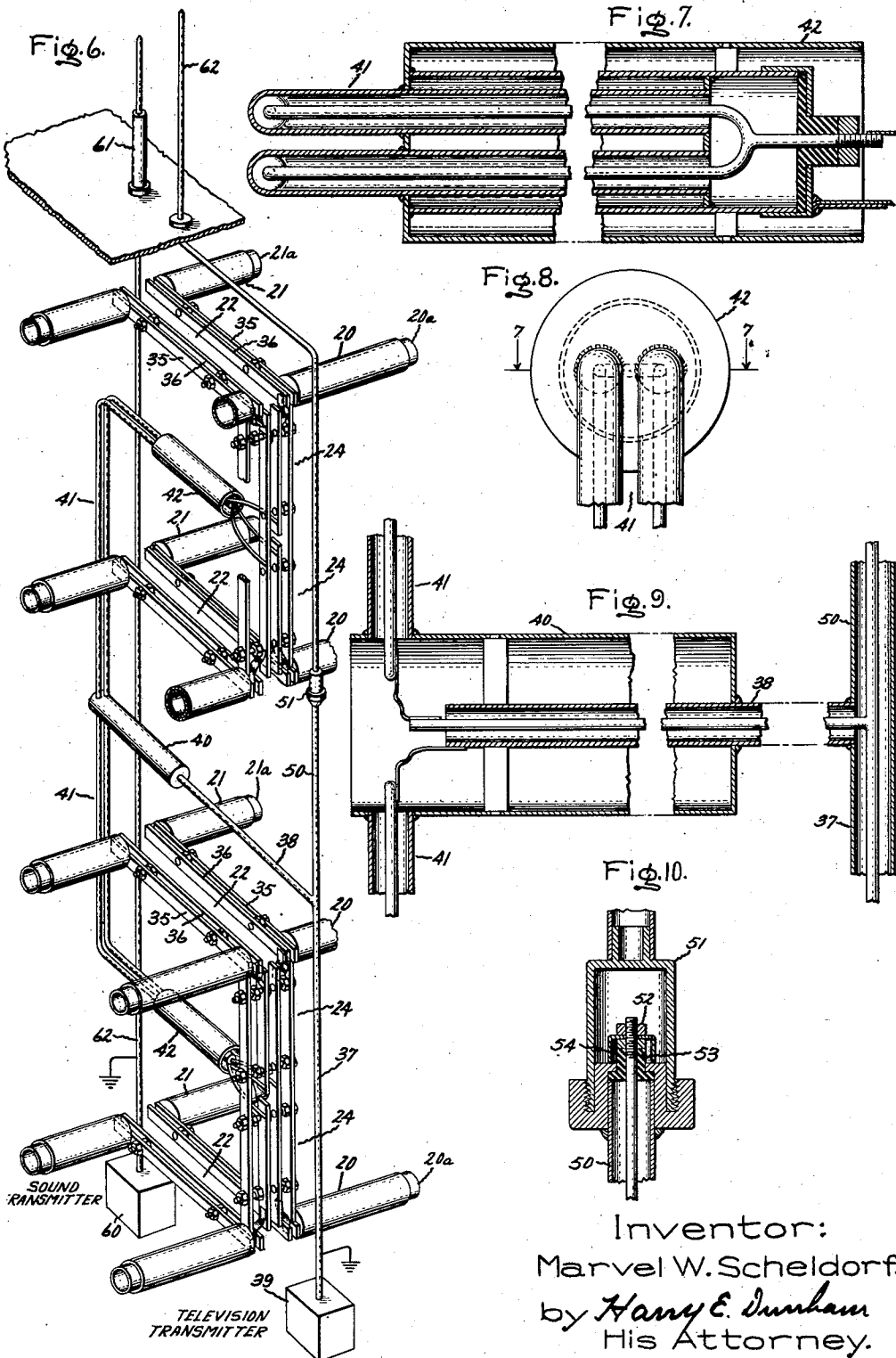
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WIDE BAND ANTENNA ARRAY

Filed July 8, 1941

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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WIDE-BAND ANTENNA ARRAY

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Application July 8, 1941, Serial No. 401,418

14 Claims. (Cl. 250—11)

My invention relates to antenna arrays and particularly to a high frequency directive antenna system for wide-band operation.

In certain types of high frequency transmission systems, for example television systems, the transmitting antenna must be designed to operate over a very wide band of frequencies. Thus, in present day television systems, the upper and lower side bands extend several megacycles on either side of the mean operating frequency to which the antenna is tuned. If the impedance of the antenna is not properly matched to the transmitting apparatus for all frequencies within this operating range, the efficiency of the system is reduced and the operating characteristics are unsatisfactory. In particular, any mismatch between the antenna and the transmission line feeding it gives rise to reflections and disturbances within the operating range of frequencies, in turn causing "ghost images" and other interference, as is well known to those skilled in the art.

It is accordingly an object of my invention to provide an improved high frequency antenna array which has uniform impedance characteristics over a wide band of frequencies on either side of the mean operating frequency to which it is tuned.

In some types of service, for example in systems for relaying television programs from one transmitting station to another, it is also desirable to employ antenna systems which possess maximum directivity in a given direction. It is a further object of my invention to provide an improved directional antenna system particularly adapted for such service.

It is specifically an object of my invention to provide an improved antenna system particularly adapted for broadcasting or relaying television programs.

Briefly, one form of transmitting antenna array constructed in accordance with my invention comprises two parallel dipole radiators which are interconnected at their feed points by a quarter wave coupling line. The general form of the system is therefore that of the letter H. A transmission feed line is connected to the feed point of one of the dipoles. For transmission this dipole then becomes an antenna and the other dipole becomes a driven reflector, or director. The radiation pattern is approximately that of a half wave dipole multiplied by a cardioid, so that considerable gain in one direction is secured.

A wide-band characteristic is obtained in ac-

cordance with my invention by a proper selection of the physical dimensions of the dipole elements so that they provide transmission loads having the same impedance characteristics over the operating band. The quarter wave coupling line between the dipoles provides a 90-degree phase difference in their energization and also acts as an impedance-inverting network. Resistance and reactance variations at the antenna feed points are thereby compensated by equal and opposite variations presented at the same point by the coupling line and its load.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic sketch of an antenna array embodying my invention; Figs. 2a-2d are idealized reactance and resistance curves which will be referred to for a better understanding of the electrical characteristics of the array of Fig. 1; Fig. 3 is a graph, prepared from data taken during experimental tests on certain antennae, showing their impedance characteristics; Fig. 4 is a perspective view, partly in section, of a practical embodiment of the antenna system of Fig. 1; Fig. 5 is a sectional end elevation of the system of Fig. 4 showing certain details of this construction more clearly; Fig. 6 is a perspective view, partly schematic, of a multiple unit television and sound antenna system embodying my invention; and Figs. 7 through 10 are fragmentary detail views of portions of the system of Fig. 6.

The active antenna elements in the array of Fig. 1 comprise two dipoles 20 and 21 which are parallel to each other and spaced apart by a quarter wave length at the mean operating frequency for which the system is designed. For reasons that will be explained later, each of the dipoles has a relatively low ratio of length to cross-section, and they are of unequal lengths, as shown. They are opened at their centers for connection to a quarter wave coupling line 22 connected between them. The coupling line 22 is illustrated as an open-wire transmission line.

High frequency energy is transferred between the array of Fig. 1 and high frequency apparatus (not shown) through a concentric transmission line 23. This line is connected to the junction between the coupling line 22 and the antenna element 20 through a quarter wave open-wire

matching line 24. The matching line 24 is designed to provide a proper impedance match between the array and the feed line 23 in a manner which will be obvious to those skilled in the art.

The direction of maximum directivity is along the axis of the coupling line 22 and toward the right as viewed in Fig. 1. Since the line 22 is a quarter wave long, the current in the dipole 21 lags the current in the dipole 20 by 90 degrees. The horizontal radiation pattern becomes that of a half wave dipole multiplied by a cardioid. Therefore under these conditions the dipole 20 may be termed the antenna unit and the dipole 21 a driven reflector, or director, unit.

The reactance and resistance of each of the dipoles 20 and 21, looking into it from its center feed point, will of course vary as the frequency of the voltages impressed thereon is varied through the natural frequency of the dipole. If satisfactory wide-band operation is to be secured, and reflections avoided, the reactance presented to the matching line 24 should be substantially zero over the entire operating band, and the resistance should be substantially constant over this range. As will be explained in greater detail below, if the dipoles 20 and 21 are made to appear as loads with identical reactance and resistance variation characteristics, at their feed connections, the variations due to one will be compensated by the variations due to the other as far as the transmission feed line is concerned. This follows from the fact that a transmission line which is an odd number of quarter wavelengths long can be utilized as an impedance-inverting network. The coupling line 22 performs this added function to assist in securing a wide-band characteristic in accordance with my invention. Briefly, the line 22 transforms the reactance and resistance characteristics of the dipole 21 so that they appear to have the opposite variations with frequency, thereby giving the required compensation. This action will become apparent from a consideration of the curves of Figs. 2a-2d in conjunction with the following detailed description.

The electrical characteristics of the system will be better understood by first considering the theoretical case of an antenna array similar to that shown in Fig. 1, but where the dipoles 20 and 21 are conductors each physically one half wave-length long. In this case the two antenna elements do not have the same terminal or driving point impedances because the terminal impedance of each element consists of two essentially separate impedances: (1) The self-impedance of the radiator which would exist if there were no other radiators in the vicinity, and (2) the mutual impedance due to the field produced by the other antenna element. The self-impedances of the dipoles are the same. However, due to mutual impedance effects, one element has increased resistance and the other element has decreased resistance by essentially the same amount. Likewise, one element has positive mutual reactance and the other negative mutual reactance. This causes the frequency of zero reactance, i. e., the resonant frequency of the element, to shift upward in one case and downward in the other case, as compared to its value for a single dipole in free space.

The idealized curves of Figs. 2a-2d, inclusive, illustrate these principles graphically. Each of these curves is drawn for variations in resistance or reactance versus frequency.

Referring first to the half-wave antenna unit, corresponding to the dipole 20 in Fig. 1 the solid line curves R_A and X_A of Fig. 2a indicate the variations in self-resistance and self-reactance as the frequency is varied through the resonant frequency f_0 . The dipole 20 derives its mutual resistance and reactance due to current in dipole 21, which lags the current in dipole 20 by 90 degrees in time phase. Consequently, the reactance variation curve is shifted toward the right and the frequency of zero reactance is increased, as is indicated by the dashed line parallel to X_A . Similarly the resistance variation curve R_A is shifted upward to some position indicated by the dashed line parallel to R_A .

The curves R_D and X_D of Fig. 2b show the corresponding self-resistance and self-reactance variations for the half-wave director unit, corresponding to the dipole 21 in Fig. 1. Since the mutual impedance in this case is due to current which leads the current in dipole 21 by 90 degrees in time phase, the signs of the mutual resistance and mutual reactance are reversed, causing the net resistance and reactance variations to be as indicated by the dashed lines.

It will therefore be apparent that dipole elements of equal lengths do not provide the proper transmission loads at their feed points and cannot be balanced against each other to compensate for their resistance and reactance variations. In order to proportion their net reactances so that both units have the same natural frequency f_0 , which is a condition required for compensation, it is necessary to lengthen the antenna element 20 and to shorten the element 21. Assuming that this has been done, then the resistance and reactance variations of one can now be compensated by the resistance and reactance variations of the other through the impedance-inverting properties of the quarter wave coupling line 22. Thus, the curves R'_D and X'_D in Fig. 2c represent the resistance and reactance characteristics looking into the coupling line 22 and its load, comprising the shortened director element. Therefore, the net resistance R_2 and the net reactance X_2 presented to the matching line 24 are generally as represented by the curves of Fig. 2d. It will be observed that the resistance presented to the transmission feed line is now substantially constant and the reactance is very nearly zero over the entire operating range.

In actual practice, when dipole elements of the usual proportions are employed, the slopes of the reactance curves are sufficiently great to prevent satisfactory compensation over a wide band. In other words, the residual reactance variations, illustrated by the curve X_2 in Fig. 2d, are too great a percentage of the value of R_2 . However, if the dipoles 20 and 21 are constructed so as to have relatively large cross-sections as compared to their lengths, the necessary conditions can be approximated over a band of frequencies sufficiently wide for practical television purposes. The electrical characteristics of the dipoles are affected in a complex manner as their diameters are increased. When conductors of larger diameters are employed, it is a well-known fact that they will both be of shorter lengths for the same resonant frequency, as compared to filamentary conductors, but in any case the antenna element will always be physically longer than the director by reason of the mutual impedance effects previously described.

In the theoretical case of filamentary conduc-

tors it would be expected that the antenna should be physically longer than a half wave length and the director physically shorter than a half wave length by approximately the same amount to provide correct compensation. However, in a particular experimental antenna array using cylindrical conductors of relatively large diameters, it was found that both elements had to be shorter than a half wave length. Thus, in this particular array the quarter-wave impedance-inverting coupling line 22 was about 18 inches long and the dipoles 20 and 21 were hollow metal cylinders each having an outside diameter of about four inches. Optimum results were secured when the impedances of the dipoles and lines were properly matched and when each half-section of the antenna unit 20 was about 14.5 inches long and each half-section of the director unit 21 about 12.5 inches long. The impedance characteristic for this particular unit is indicated by the curve 25 in Fig. 3. For comparison, curve 26 shows the results secured for the same system when adjusted for optimum conditions and when both units were of equal length, each half-section being about 13.25 inches long. It is obvious that satisfactory results were only secured when the elements were properly proportioned in accordance with my invention.

Figs. 4 and 5 show a practical embodiment of the antenna system of Fig. 1. Corresponding reference numerals have been applied to corresponding elements. The dipoles 20 and 21 each comprise two tubular metal cylinders mounted in axial alignment. Each section of the antenna element 20 is closed at its inner end and carries an inner metal cylinder 20a extending beyond its outer end, as shown. A tight sliding fit is maintained between the inner cylinders 20a and the sections of the element 20 so that the effective length of each section may be adjusted. The two sections of the director element 21 are similarly provided with inner cylinders 21a for adjusting the lengths of these sections.

In the antenna structure illustrated in Figs. 4 and 5, the conductors of the quarter-wave coupling and matching lines 22 and 24 are in the form of L-irons, as shown. This construction permits ready adjustment of the conductor spacings in order to give the lines proper characteristic impedances for matching all elements of the system correctly. The feed connections to the sections of the dipoles 20 and 21 are made at the lower edges of their inner ends, where they are secured to the coupling line conductors 22 in any suitable manner, as by soldering, brazing, welding, or the like.

For horizontally polarized operation the entire antenna assembly is preferably mounted upon cross arms 27 at the top of a single supporting pole 28, as illustrated. The concentric transmission feed line 23 is secured alongside the supporting pole and connected to the lower end of the matching line 24 through the flexible connections 29.

In order to permit unbalanced operation of the transmission line 23 with one conductor grounded and yet provide balanced operation of the array with respect to ground, the "elevator" section 30 is employed. Its construction and operation are familiar to those skilled in antenna design and require no detailed explanation here. Briefly, it comprises an outer cylinder 30 having its upper end free and its lower end secured to the outer conductor of the line 23 at a point spaced from the upper rim of the outer conductor by

one-quarter wave length at the mean operating frequency. Due to the impedance-inverting characteristics of a quarter wave line, a high impedance exists between the upper rim of the sleeve 30 and the adjacent rim of the outer conductor of the line 23. Consequently, the upper end of the outer conductor of the transmission line 23 is effectively isolated from ground for radio frequency potentials and is free to "float" so that balanced operation of the array may be attained.

Greater gain in a given horizontal direction may be secured by using a multiple unit antenna system composed of a plurality of unit arrays of the form just described. In this type of system the unit arrays are similarly oriented and spaced apart along a common vertical axis. A television system employing four unit arrays is illustrated in Fig. 6. Each of the unit arrays is essentially of the same form as shown in Fig. 4. However, in the embodiment illustrated in Fig. 6, each of the coupling line conductors 22 comprises an outer bar 35 fixedly secured at its ends to the dipoles 20 and 21, and an inner bar 36 adjustably mounted on the outer bar by means of adjusting studs and nuts. This construction provides a simple means for adjusting the spacings between the respective transmission line conductors for impedance matching purposes. A similar transmission line construction is also employed for the four matching sections 24, as is clearly shown in the drawings.

The four unit arrays in Fig. 6 are fed in parallel from a common concentric transmission line 37, 38 which is supplied from a suitable source of television signals indicated schematically by the box 39. Energy is supplied through the vertical portion 37 and the horizontal portion 38. The portion 38 is positioned halfway between the two inner unit arrays. Transition to balanced feed is obtained through an elevator section 40. The constructional details of a preferred form of this elevator will be apparent without detailed discussion from an inspection of Fig. 9 which shows a vertical sectional view through the elevator and the transmission line 37, 38.

The feed connections divide into an upper branch 41 feeding the upper pair of unit arrays and a lower branch 42 feeding the lower pair of unit arrays. These two branches are symmetrical and, in the particular form illustrated, each comprises two concentric lines in parallel. This arrangement is employed to secure a proper match between line 38 and the combination of lines 41 and 42.

Each of the branch lines 41 is connected to one pair of matching lines 24 through an elevator 42. It is believed that the details of construction of these elevators will be obvious from an inspection of Figs. 7 and 8, which show respectively a horizontal section through either one of the elevators and an end elevation looking toward the left-hand end of the upper elevator 42.

In order to provide a support for the inner conductor of the transmission line 37 and to prevent the inner conductor of the transmission line 38 from being bent downwardly due to the weight of the parts, the transmission line 30 is extended vertically a quarter of a wave length above its junction with the line 38, as is indicated by the section 50 in Fig. 6. As is shown more clearly in the fragmentary sectional view of Fig. 10, the inner transmission line conductor terminates within a cylindrical junction box 51.

Its upper end is threaded and provided with nuts 52 which in turn support the inner conductor through a thrust mounting comprising an insulating bushing 53 which is seated upon the upper end of the outer transmission line conductor. A metal shorting cap 54 is provided for short-circuiting the transmission line 50 at this point. It will be apparent that this produces a high impedance at the junction of sections 37 and 38. In some cases it may be desirable to replace the shorting cap 54 by impedance elements for compensating purposes.

The television antenna structure illustrated in Fig. 6 also incorporates a sound transmission system. A suitable source of sound signals to accompany the television signals is indicated schematically by the box 60. It is connected to an antenna 61 through a concentric feed line 62. In order to give the antenna 61 a directional characteristic, with maximum radiation in the same direction as the television antenna system, a grounded vertical reflector 62 is provided adjacent the antenna 61 and suitably spaced therefrom. This reflector 62 may constitute an extension of the grounded outer conductor of the transmission line 37 feeding the television antenna, as shown. It also extends to a higher point than the upper end of the antenna 61 so that it performs the additional function of a lightning rod for the protection of both the sound system and the television system.

Referring again to Fig. 6, it should be noted that the lengths of all the antenna elements 20, and of all the director elements 21, will not necessarily be the same if all elements are to provide proper transmission loads at their driving points for reactance and resistance compensation in accordance with my invention. Neither will they in general be of the same lengths as the corresponding elements in a single array, such as is shown in Fig. 4. The reason for this of course lies in the fact that there is mutual impedance between the several unit arrays as well as between the dipoles of each array.

In general it will be necessary to determine the correct length for the elemental dipoles in any given form of system by actual operating tests. Their physical dimensions for correct compensation cannot be calculated exactly because of the many interdependent quantities involved, most of which are not known with any degree of certainty. For example, even in the simple array of Fig. 4, all of the following quantities affect the physical dimensions of the elements and none of these quantities is capable of exact calculation by known methods: (1) The ratio of the currents in the elements, (2) the mutual impedance between elements of different lengths, (3) the mutual impedance between conductors of large cross-sections as compared to their lengths, (4) capacity effects between the inner ends of the large conductors forming each dipole, and (5) the capacity "end effects" of the coupling line.

It will also be apparent that various modifications may be made in the construction of antenna arrays utilizing the principles of my invention. In some cases it may be desirable to use conductors of unequal diameters for the dipoles. It has also been indicated earlier that the two dipoles might in some cases be coupled together through a coupling line greater than a quarter wave length long and equal to an odd number of quarter wave lengths. Under some circum-

stances it may also be desired to connect each of the dipoles to its feed point, at one end of the coupling line 22, through additional impedance-matching or coupling lines. Therefore, while I have illustrated what I believe to be preferred embodiments of my invention, I do not wish to be limited thereto since many such modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. An antenna system comprising, in combination, two substantially coplanar, linear antenna elements, each element being connected to a feed point, impedance-inverting means interconnecting said feed points, said means comprising a transmission line having a length substantially equal to an odd multiple of a quarter wave length at the mean operating frequency of the system, and a feed line connected to one of said feed points, the physical dimensions of said elements being so proportioned that, over a predetermined band of frequencies including said mean frequency, the reactance and resistance variations with frequency looking from said one point into the element connected thereto are substantially equal and of opposite slope to the reactance and resistance variations with frequency looking into said line from said one point.

2. A high-frequency directive antenna array comprising, in combination, a pair of substantially parallel dipoles spaced apart by substantially one quarter of a wave length at the mean operating frequency of the system, each dipole being connected to a feed point, an impedance-inverting line interconnecting said feed points, said line having a length substantially equal to an odd multiple of a quarter wave length at said frequency, and a transmission line connected to one of said feed points, the physical dimensions of said dipoles being so proportioned that, over a predetermined band of frequencies including said mean frequency, the reactance and resistance variations with frequency looking from said one point into the dipole connected thereto are substantially equal and of opposite slope to the reactance and resistance variations with frequency looking into said line from said point.

3. The combination, in a high-frequency directive antenna system, of a dipole antenna unit, a dipole director unit substantially parallel to said antenna unit and spaced therefrom by substantially one quarter wave length at the mean operating frequency of the system, an impedance-inverting line interconnecting said units, and a transmission feed line connected to said antenna unit, said units having substantially equal feeding point resistances and reactances at any frequency within a predetermined band of frequencies extending on either side of said mean operating frequency.

4. A high-frequency transmitting antenna array comprising, in combination, a horizontal dipole antenna element, a horizontal dipole director element substantially parallel to said antenna element and spaced therefrom by substantially one quarter wave length at the mean operating frequency of the array, each of said elements having a center feed connection, impedance-inverting means connected between said feed connections, and a transmission line adapted to supply high frequency energy to said

array connected to said antenna feed connection, said elements having substantially equal feeding point resistances and reactances at any frequency within a relatively wide band of frequencies extending on either side of said mean operating frequency.

5. An antenna system comprising, in combination, two substantially coplanar, linear antenna elements of unequal physical lengths, the length of at least one of said elements being substantially different from a half wave length or an integral multiple thereof at the mean operating frequency of the system, each element being connected to a feed point, impedance-inverting means interconnecting said feed points, and a transmission line connected to one of said feed points.

6. In a directive antenna system for operation on high frequencies extending over a relatively wide band, the combination comprising a first linear antenna element, a second linear antenna element substantially parallel to said first element and spaced therefrom by substantially one quarter of a wave length at the mid-band frequency, each element being connected to a feed point, impedance-inverting means connected between said feed points, and a transmission line connected to one of said feed points, said elements having unequal lengths so selected that their respective feed point reactances and resistances are substantially equal at any frequency within said band, whereby the impedance presented to said transmission line by said system at said one feed point is substantially uniform over said wide band of frequencies.

7. In a directive antenna system for transmitting waves of high frequencies extending over a relatively wide band, the combination comprising a dipole antenna unit, a dipole director unit substantially parallel to said antenna unit and spaced therefrom by substantially one quarter of a wave length at the mid-band frequency, each element being connected to a feed point, an impedance-inverting line coupling said feed points together, and a transmission feed line connected to the feed point for said antenna unit, the physical dimensions of said units being so proportioned that, over said wide band, the reactance and resistance variations with frequency looking into said antenna unit from said antenna feed point are substantially equal and of opposite slope to the reactance and resistance variations with frequency looking into said impedance-inverting line from the same point, whereby the impedance of said system is substantially uniform over said wide band.

8. A wide-band high-frequency transmitting antenna array comprising, in combination, a pair of substantially parallel dipoles spaced apart by substantially one quarter of a wave length at the mean operating frequency, each of said elements being connected to a feed point, an impedance-inverting transmission line interconnecting said feed points, said line having a length substantially equal to an odd multiple of a quarter wave length at said frequency, and a transmission feed line connected to one of said feed points, said dipoles having substantially different ratios of length to cross-section such that, over a wide band of frequencies on either side of said mean frequency, their respective feed point reactances and resistances are substantially equal at any frequency within said band, whereby the reactance presented to said feed line by the array is substantially zero and the

resistance presented to said feed line by the array is substantially constant.

9. In a wide-band directive antenna system, the combination comprising two substantially parallel dipoles of comparable cross sections and of substantially different physical lengths, said dipoles being spaced apart by substantially one quarter of a wave length at the mid-band frequency, an impedance-inverting means interconnecting said dipoles, and a transmission line connected to one of said dipoles.

10. In a directive antenna system for transmitting waves of high frequencies extending over a relatively wide band, the combination comprising, a substantially cylindrical dipole antenna, a substantially cylindrical dipole director parallel to said antenna and spaced therefrom by substantially one quarter of a wave length at the mid-band frequency, said antenna and said director each having a center feed point, an impedance-inverting line connected between said points, said line having a length substantially equal to an odd multiple of a quarter wave length at said frequency, and a transmission feed line connected to the antenna feed point, said antenna having a cross-section comparable to said director and a physical length substantially greater than said director.

11. In a directive antenna system for transmitting waves of high frequencies extending over a relatively wide band, the combination comprising, a substantially cylindrical dipole antenna, a substantially cylindrical dipole director parallel to said antenna and spaced therefrom by substantially one quarter of a wave length at the mid-band frequency, said antenna and said director each having a center feed point, an impedance-inverting line connected between said points, said line having a length substantially equal to an odd multiple of a quarter wave length at said frequency, and a transmission feed line connected to the antenna feed point, said antenna having a cross-section comparable to said director and a length substantially greater than said director, said lengths being such that, over said wide band of frequencies, the reactance and resistance variations with frequency looking into said antenna from said antenna feed point are substantially equal and of opposite slope to the reactance and resistance variations with frequency looking into said impedance-inverting line from the same point, whereby the impedance of said system is substantially uniform over said wide band.

12. A wide-band transmitting antenna array comprising, in combination, a cylindrical dipole antenna element, a cylindrical dipole director element parallel thereto and spaced therefrom by substantially one quarter wave length at the mean operating frequency, each of said elements being connected to a feed point, a quarter wave transmission line interconnecting said feed points, and a transmission feed line connected to the antenna feed point, each of said elements having a relatively low ratio of length to diameter and said antenna element being physically longer than said director element.

13. A wide-band transmitting antenna array comprising, in combination, a cylindrical dipole antenna element, a cylindrical dipole director element parallel thereto and spaced therefrom by substantially one quarter wave length at the mean operating frequency, each of said elements being connected to a feed point, a quarter wave transmission line interconnecting said feed

points, and a transmission feed line connected to the antenna feed point, each of said elements having a relatively low ratio of length to diameter and said antenna element being physically longer than said director element, the lengths of said elements being so adjusted that, over a wide band of frequencies on either side of said mean frequency, their respective feed point reactances and resistances are substantially equal at any frequency within said band, whereby the reactance presented to said feed line by the system is substantially zero and the resistance presented to said feed line by the system is substantially constant.

14. A directive antenna system adapted to operate on a wide band of high frequencies comprising, in combination, two substantially parallel dipoles spaced apart by substantially one quarter of a wave length at the mid-band frequency, impedance-inverting means interconnecting said elements, and a transmission feed line connected to one of said dipoles, said dipoles having substantially equal values of reactance and equal values of resistance at any frequency within said band.

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