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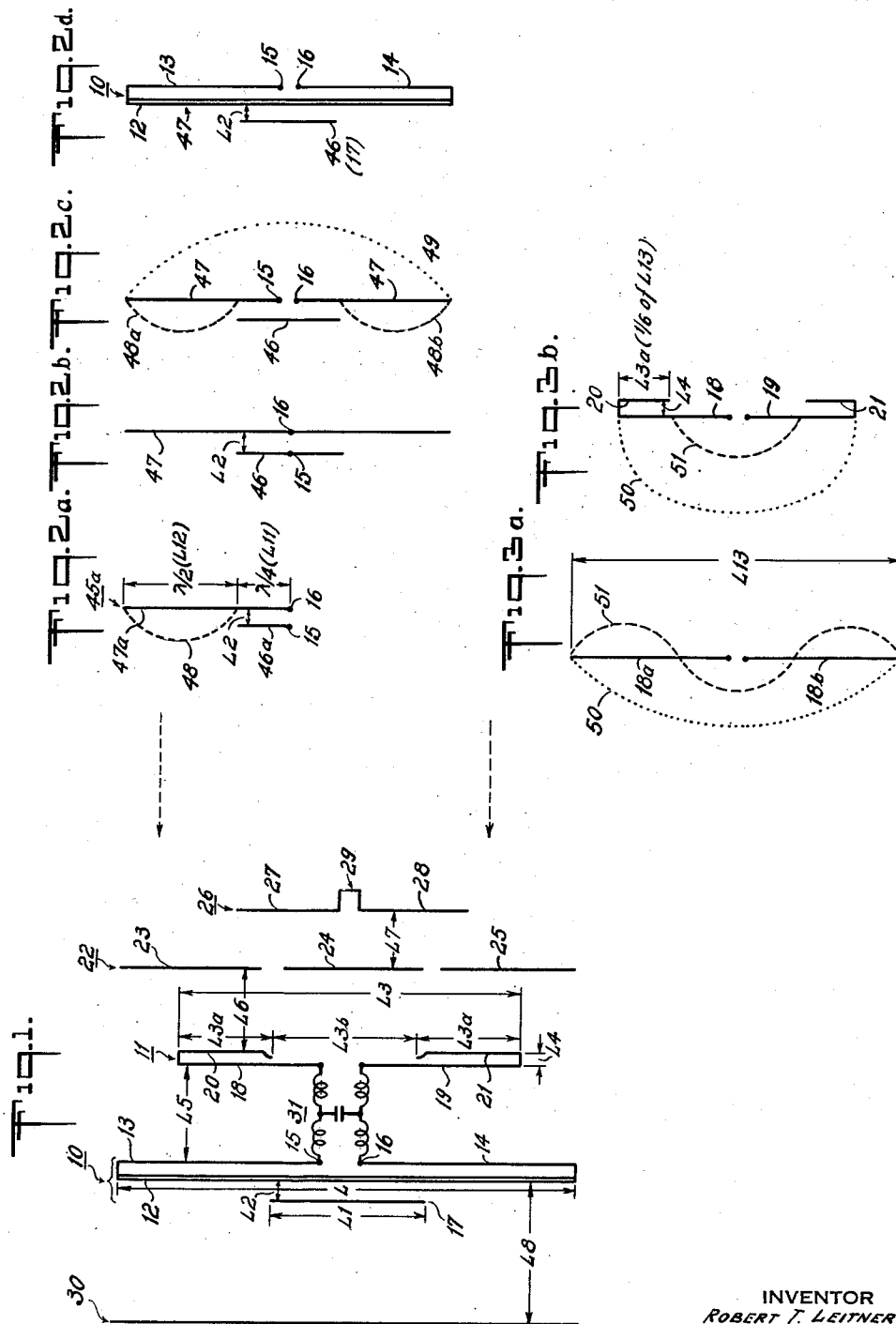
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2,799,018

WIDE BAND HIGH GAIN ANTENNAS

Filed July 11, 1956

4 Sheets-Sheet 1



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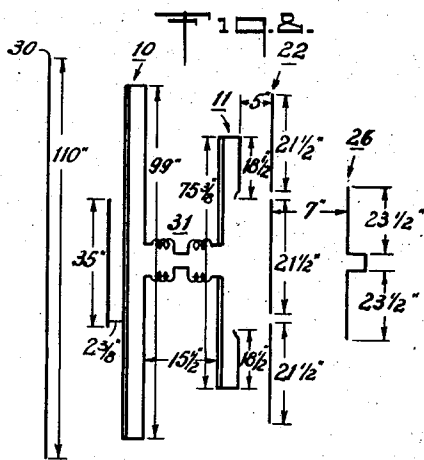
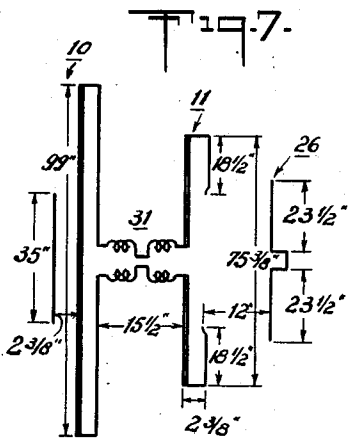
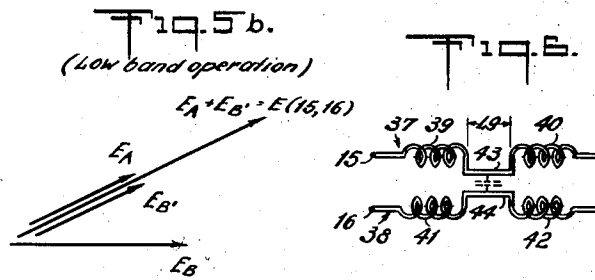
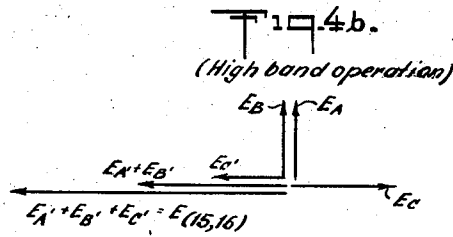
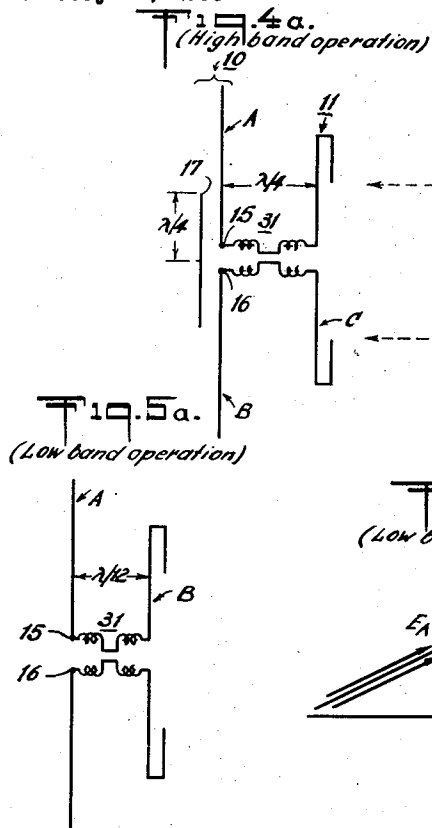
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4 Sheets-Sheet 2



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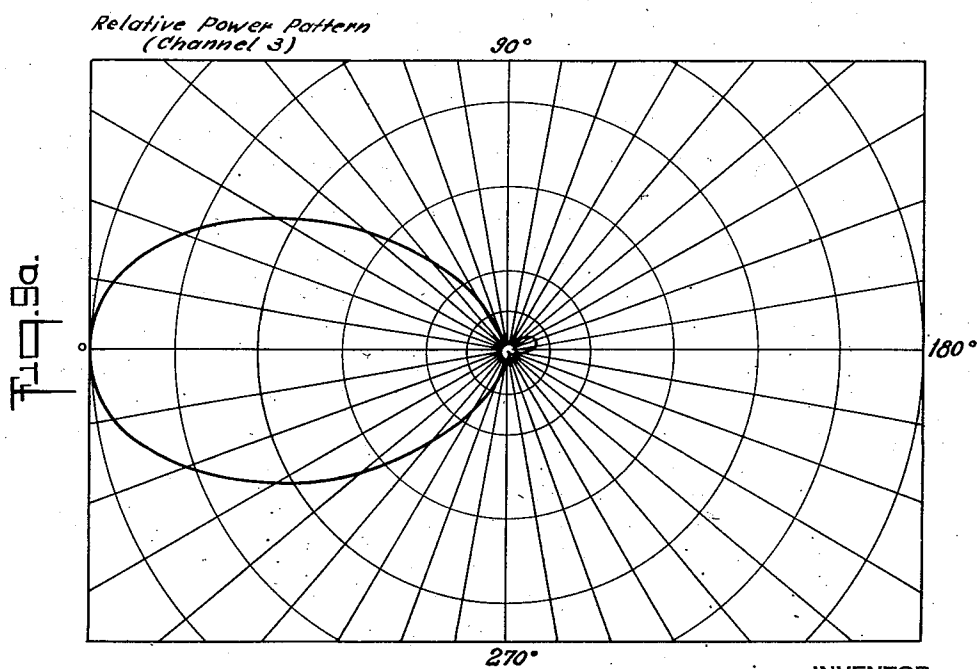
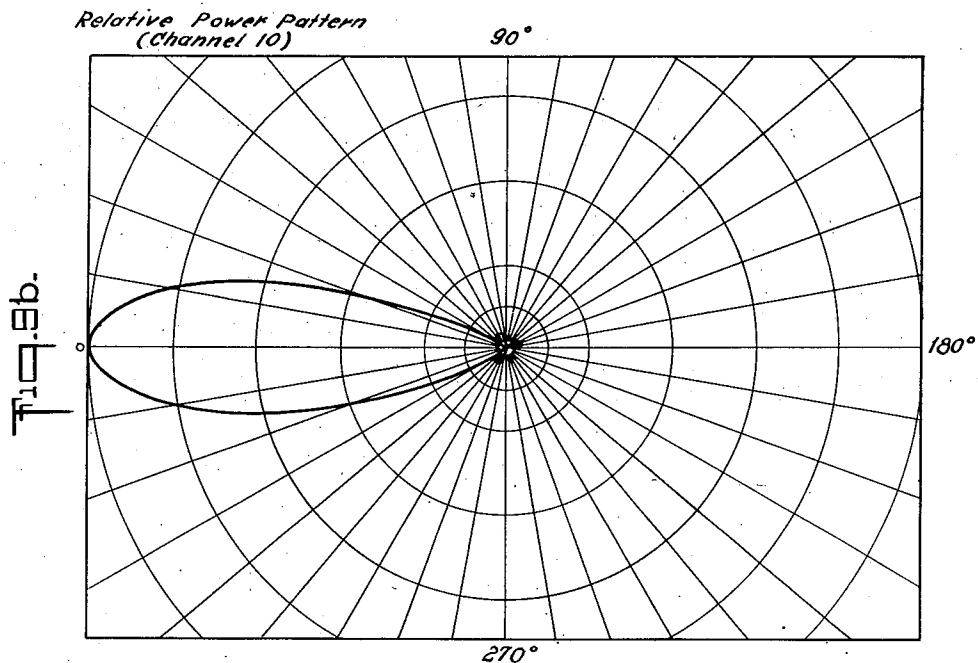
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4 Sheets-Sheet 3



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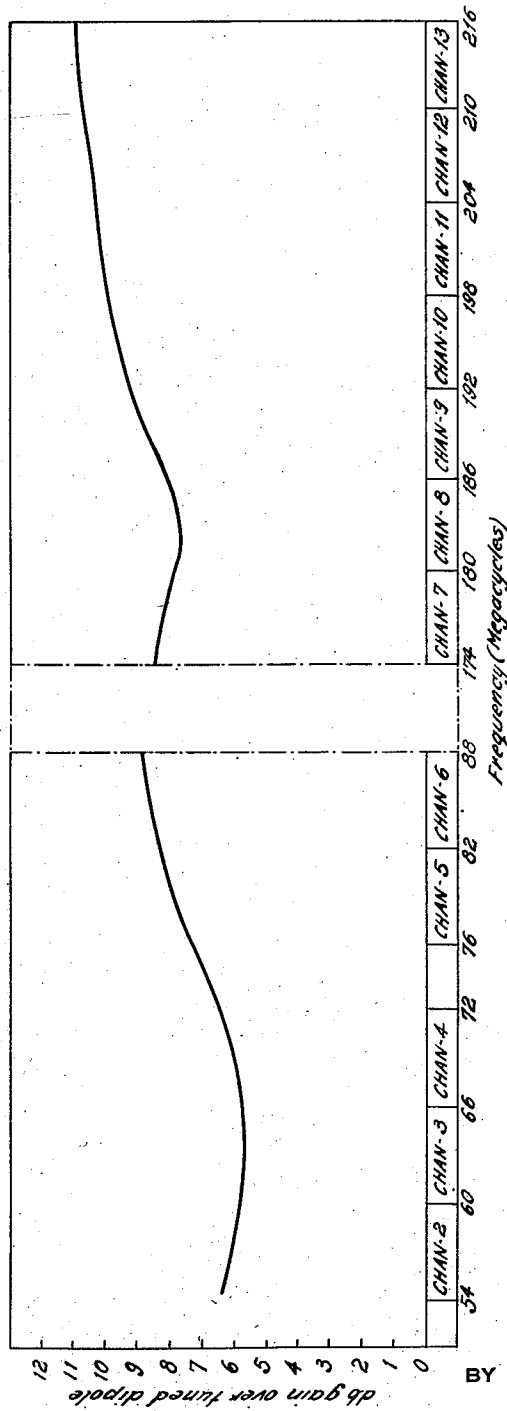
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Fig. 10.



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WIDE BAND HIGH GAIN ANTENNAS

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14 Claims. (Cl. 343—814)

This invention relates to antennas, and more especially it relates to antennas which are required to have high gain at widely different frequency operating bands.

A principal object of the invention is to provide a directionalized antenna which is capable of highly efficient operation at two relatively widely spaced frequency bands, such for example as the presently assigned low and high frequency television bands of 54 to 88 megacycles and 174 to 216 megacycles, respectively.

Another object is to provide a wide frequency band receiving antenna employing two driven dipole elements which are electrically connected by a special delay line to a common feed line, whereby more efficient addition of the induced currents in both dipoles is automatically achieved.

A feature of the invention relates to an antenna having a novel combination of dipole driven elements, one of which is designed to act as an end loaded dipole at the lower frequency band, while acting as a half-wave dipole at the higher frequency band, the other dipole being interconnected with the first dipole by a special frequency selective delay line to bring the induced currents in both dipoles into additive phase for application to a feed line which is connected to both dipoles.

Another feature relates to a wide frequency band receiving antenna having two driven dipole units for connection to the same feed line, one unit having associated therewith in relatively closely spaced parallelism, a quarter-wavelength element to constitute with the said one unit a specially designed equivalent transmission line which comprises the said one section throughout its physical length as an efficient half-wave antenna at the low frequency band. The other dipole unit of the pair is especially designed to act as an end loaded dipole whereby at the low frequency band its entire length acts as a half-wavelength dipole while at the higher frequency band only its center section acts as a half-wave dipole, but with the current flow in the same phase for both the high and the low frequency bands, in conjunction with a special delay line interconnecting both units to bring their combined induced currents into additive phase for both the high and low frequency bands.

A still further feature relates to the novel organization, arrangement and relative location and interconnection of parts which cooperate to provide an improved directional and broad band antenna.

Other features and advantages will be apparent after a consideration of the following detailed descriptions and the appended claims.

In the drawing,

Fig. 1 is a schematic plan view of an antenna embodying the invention;

Figs. 2a, 2b, 2c, and 2d are simplified schematic diagrams used in explaining the operation of Fig. 1;

Figs. 3a and 3b are additional simplified schematic diagrams used in explaining Fig. 1;

Fig. 4a is a schematic diagram of the two driven dipole

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elements of Fig. 1 to explain the relative phasing of the currents therein when operating at the high frequency band;

Fig. 4b is a vector diagram corresponding to the operation of Fig. 4a;

Fig. 5a is a schematic diagram of the two driven dipole elements of Fig. 1 to explain the relative phasing of the currents therein when operating at the low frequency band;

Fig. 5b is a vector diagram explanatory of Fig. 5a;

Fig. 6 is a detailed view of the special delay line embodied in Fig. 1;

Fig. 7 is a modification of the antenna of Fig. 1 embodying a parasitically driven director element;

Fig. 8 is a modification of the antenna of Fig. 1 showing a plurality of parasitically driven director elements and a parasitically driven reflector element to constitute an over-all antenna of the generic Yagi kind;

Figs. 9a and 9b are respective power pattern diagrams of the antenna of Fig. 1 when receiving, respectively, signals in the low frequency and high frequency bands;

Fig. 10 is a graph showing the relation between received frequency and decibel gain.

Referring to Fig. 1 of the drawing the antenna therein shown comprises two driven dipole units 10, 11. Unit 10 is preferably, although not necessarily, of the folded dipole kind constituted, for example, of a rigid wire rod 12 whose physical length L is so chosen that at the lower frequency band (for example 54 to 88 megacycles) it operates as a half-wave antenna, and with the folded arms 13, 14 of finer wire. The spacing of the arms 13, 14 with respect to rod 12 is in accordance with well known folded dipole theory so as to provide it with a pair of relatively closely spaced feed points 15, 16 and to impart the desired half-wave operation at the desired low frequency.

The unit 10 also includes, mounted in closely spaced parallel relation to the center third of element 12 and rearwardly thereof the straight wire or rod element 17, the physical length L1 of which is approximately one-third the length L. For example, when used in the present assigned television high and low frequency bands, the length L of unit 10 may be approximately 99 inches. The length L1 of element 17 may be approximately 35 inches with the spacing L2 between elements 12 and 17 being approximately $2\frac{3}{8}$ inches. The unit 11 consists of two rigid wire elements 18, 19 having a length L3 of approximately 75 inches, and having their ends 20, 21 bent back upon themselves with the bent back length L3a of each approximately one-sixth of a wavelength referring to the high frequency band. The bent back portions 20 and 21 may each be of a length L3 of approximately $18\frac{1}{2}$ inches and are closely spaced, for example at a distance L4 of approximately $2\frac{3}{8}$ inches, with respect to their associated elements 18, 19, while the combined length of elements 18 and 19 may be approximately 75 inches. This leaves the center length L3b of approximately 37 inches which is in line with the center one-third of unit 10. Because of the close spacing between the elements 18, 20 and 19, 21, the unit 11 constitutes in effect an end loaded dipole so that in the high band only the center third of unit 11 acts as a half-wave antenna, and the end sixths are practically ineffective. However at the low band the entire length of unit 11 is effective as a half-wave antenna. Unit 11 is spaced from the unit 10 a physical distance L5 which is approximately one-quarter wavelength at the high frequency band and approximately one-twelfth wavelength at the low frequency band. This spacing L5, for example, may be approximately $15\frac{1}{2}$ inches.

Mounted in spaced parallelism to and in front of the unit 11 is a parasitically driven director unit 22 consisting of three co-linear spaced metal rods 23, 24, 25. Rods 23

and 25 may be approximately $21\frac{1}{2}$ inches long and rod 24 may be approximately 22 inches long. The spacing L6 between unit 22 and unit 11 may be approximately 5 inches. Mounted in spaced parallelism to and in front of the director unit 22 is another parasitically driven director unit 26 consisting of two co-linear one-half wavelength metal rods 27, 28, each of which may be approximately $23\frac{1}{2}$ inches long and joined at their adjacent gapped ends by a one-quarter wave stub transmission line 29. The stub 29 is designed so that it has a maximum impedance at a frequency well above the resonant frequency of the units 10 and 11. The spacing L7 between the units 22 and 26 may be approximately one-tenth to one-fifth wavelength and is under the above conditions approximately 7 inches.

Mounted in spaced relation to and in the rear of unit 10 is a parasitically driven reflector element 30 which in accordance with well known reflector theory is spaced a distance L8 from the unit 10 which is a distance of approximately one-tenth to one-fifth wavelength at the low frequency band. This spacing L8, for example, may be approximately 26 inches and the reflector 30 may be in the form of a rigid metal rod of approximately 110 inches length. It will be understood that the various units 10, 11, 22, 26 and 30 are mounted on a suitable boom (not shown). If the boom is of metal the element 30 can be directly attached thereto since it need not be insulated therefrom. However the elements 10, 11, 22 and 26 should be insulatingly supported from the boom, for example in the manner disclosed in U. S. Patent 2,705,283.

In accordance with the invention, the two dipole driven units 10 and 11 are connected by a special wave delay line 31, one end of this line being connected to the feed line points 15 and 16 and the other end of the delay line being connected to the gapped ends of the elements 18 and 19. The line 31 is essentially a balanced T-section composed of inductive series elements 32, 33, 34, 35 which have a capacitive shunt 36 therebetween. The line 31 is so designed that the transmission of signals in the high frequency band is delayed a predetermined amount, as will be described hereinbelow, whereas for the low frequency band the reactance of the line 31 is such that the transmission essentially is undelayed. The line 31, in accordance with one phase of the invention and as shown in detail in Fig. 6, comprises two legs 37, 38. Each of these legs includes two coils 39, 40 and 41, 42 with an intervening uncoiled straight portion 43, 44. Each leg may be formed from a one-eighth inch cross-section aluminum wire with each of the coils 39 to 42 having a coil diameter of approximately three-quarter inch and with 6.5 turns, and with the adjacent turns of each coil spaced $\frac{3}{16}$ inch. The straight portions 43, 44 are relatively close together so as to provide the requisite shunt capacitance 36. The length L9 of the sections 43, 44 may, under the above assumed conditions, be of approximately seven inches and the spacing L10 may be approximately one inch.

We have found that by constructing the antenna as above described, it is possible to receive signals in widely spaced frequency bands, for example those presently assigned to channels 2 to 6 and 7 to 13, with high gain and with a high order of directional sensitivity, as illustrated in the graph of Fig. 10 which shows horizontal radiation patterns for high and low band operation and the corresponding gain curves. In order fully to understand the theory of operation of the antenna shown in Fig. 1, reference may be had to Figs. 2a to 2d. The analysis will be predicated upon a frequency separation and wavelength between the high and low bands involving a factor of 3.

Referring to Fig. 2a, the numeral 45a represents a basic end fed antenna constituted from an ordinary open wire transmission line comprising wires or rods 46a, 47a with the wire 46a cut shorter than the wire 47a by one-half wavelength at the center of the high band of frequencies.

In other words, the length L11 of the wire 46a would be approximately one-quarter wavelength at the said high band frequency and the non-overlapped length L12 of wire 47a would be a half wavelength at the said frequency. The feed line to the antenna is connected to the points 15, 16. The instantaneous current distribution along the length L12 is represented by the dotted line 48.

Fig. 2b shows two transmission line antennas of Fig. 2a spaced end to end and fed in parallel from the feed points 15, 16. This antenna then comprises the straight bar 47 and the closely spaced bar 46, and results in an antenna which is three half-wavelengths long at the high band, and approximately one-half wavelength long at the low band. However because of this method of feeding the antenna the operation at low band frequencies is rather inefficient.

In order to overcome this inefficiency, the antenna instead of being fed in parallel can be fed in series, as shown in Fig. 2c. The antenna of Fig. 2c improves the high band characteristic by increasing the impedance and at low band it provides a low band center-fed half-wave dipole. Thus the short bar or conductor 46 associated with the element 47 becomes one conductor of a two-wire transmission line which is one-half wavelength long at high band frequencies and because of the short length of bar 46 its effect at the low band frequencies is negligible. The low band impedance is greatly improved without any sacrifice in the high band operation. The resulting antenna is extremely effective at low band and especially at the lower frequency end, that is, the longer wavelength. At the high band the effectiveness is obtained by having two end-fed half-wave elements whose signals add in phase by a series connection. This improves the impedance characteristics and results in a single-lobed pattern. The instantaneous current distribution at the high band is represented by the dashed line curves 48a, 48b, while the instantaneous current distribution in the low band is represented by the dotted line curve 49.

A further improvement at the low band operation can be obtained by converting the element 47 into a folded or stepped up dipole, as indicated in Fig. 2d. This results in a combination 10 which is the same as the unit 10 above described in connection with Fig. 1.

With respect to the evolution of the unit 11 of Fig. 1, reference may now be had to Figs. 3a and 3b. In Fig. 3a there is shown a center fed dipole consisting of the arms 18a, 18b having a physical length L13 which is three half-wavelengths long at high band or one-half wavelength long at low band. By folding the arms 18a and 18b at a point approximately one-sixth of the length from the ends of those arms, there results the antenna unit 11 shown in Fig. 3b which is the same as the unit 11 described above in connection with Fig. 1.

The instantaneous current distribution in the antenna of Fig. 3a at the low band operation is represented by the dotted curve 50, while the instantaneous current distribution at the high band operation is represented by the dashed line curve 51. It will be seen that the end portions of the curve 51 are out of phase with the end portions of the curve 50. However, in Fig. 3b the corresponding current distributions at the low and high bands are in phase at the central region of the antenna and the current distribution at low band operation is improved at the end sections of the unit. Because of the close spacing L4 between the folded back portions 20 and 21 and the straight portions 18, 19, the antenna of Fig. 3b at low band operates as an end loaded dipole with the current distribution represented by the curve 50. Its operation over the low band channels is very effective, especially at the high end of the low band. As indicated in Fig. 3b, the high current density at the center of the low band operation has been unaffected and the relatively small current at the ends contributes very little. At the high band operation the out-of-phase currents at the

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ends of the element have cancelled each other, resulting in an in-phase element of current.

In order to achieve the special advantages of the units 10 and 11 in combination, it is necessary that the signals induced in both units 10 and 11 by the received radiation be in additive phase at their points of connection 15, 16 to the common feed line. In accordance with the invention, the two units 10 and 11 are connected by a special network 31 (Fig. 6) which takes into account the phase shift encountered by reason of the transmission line character of the unit 10, which, of course, includes the element 17. Accordingly the line 31 must be designed to have the requisite phase delay and it must be automatically frequency selective. The manner in which the frequency selective line 31 insures additive in-phase signals will now be explained in connection with Figs. 4a, 4b and 5a and 5b. Figs. 4a and 4b explain the high frequency band operation, and Figs. 5a and 5b explain the low frequency band operation.

For purposes of simplicity, Fig. 4a shows the dipole of the unit 10 as a simple or non-folded dipole. Fig. 4b shows the vector relationships of the signals as they are induced on the elements 10 and 11 and as they are additively combined at the output terminals 15, 16. Merely for convenience of vector representation, the two parts of the dipole unit 10 are labeled A and B, and the unit 11 is labeled C. In Fig. 4b the vectors EA, EB, EC represent the voltages induced on the corresponding elements A, B, C of Fig. 4a, whereas the primed vectors in Fig. 4b represent the individual signals as they appear at the output terminals 15, 16. From an examination of Fig. 4b the induced signal EC leads the EA and EB signals by 90 degrees because of the space separation between the units 10 and 11 which at the high frequency band is one-quarter wavelength. The signals EA and EB are further retarded in phase by 90 degrees in traveling through the transmission line path constituted of the dipole A, B and the element 17 as a transmission line feeding the terminals 15, 16 as above described. If EC is to be additive in phase at the output terminals 15, 16, this signal EC must be delayed by 90 degrees plus 90 degrees, or 180 degrees in traveling over the quarter-wavelength transmission line 31. The delay line 31 automatically performs this function by giving the 180 degree phase shift over a 90 degree path length. At low band frequencies the delay line 31 acts as an ordinary straight transmission line of approximately 30 electrical degrees in length.

The operation at low band frequencies is diagrammatically and vectorially illustrated in Figs. 5a and 5b from which it will be seen that the delay line 31 acts as an ordinary straight transmission line of 30 electrical degrees in length, thus at low band frequency operation the signals add in-phase at the terminals 15, 16 as illustrated in the vector diagram of Fig. 5b.

It will be understood, of course, that the parasitic director units 22, 26 and the parasitic reflector unit 30 do not change the above-described vector relationships and the phase and frequency selective operation between the units 10, 11 and 31.

It will be further understood that the invention is not limited to the particular number of director and reflector units shown in Fig. 1. In fact the invention finds superior advantages in an antenna employing the units 10 and 11 alone, but for purposes of greater directional sensitivity one or more director units and one or more reflector units may be employed in combination with the units 10 and 11, as shown in Figs. 7 and 8.

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention.

What is claimed is:

1. An antenna for receiving radiation in relatively widely spaced frequency bands, comprising two units arranged in substantially coplanar array, each of said units being a half-wave dipole, a conductor mounted in

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closely spaced relation rearwardly of the center section of the first dipole to render only the outer end sections of the first dipole effective in the high frequency band, the other unit comprising a dipole mounted forwardly of the first dipole and having its outer end sections reactively loaded to render substantially only the center section of the second dipole effective at the high frequency band, and a phase delay line interconnecting the two dipoles with a pair of output terminals to bring the induced currents arriving at said terminals into additive in-phase relation for both bands.

2. An antenna for receiving radiation in two relatively widely spaced frequency bands, comprising first and second center-fed dipoles mounted in substantially coplanar array, the first dipole being of a length to constitute it approximately three one-half wavelengths long at the higher band and approximately one-half wavelength long at the low band, means associated with the center section of the first dipole to render only the outer end sections effective as half-wave antennas at the higher band, but without substantially affecting the first dipole as a half-wave antenna at the low band, the second dipole being of a length to constitute it a half-wavelength antenna at the low band while constituting its center section alone as a half-wave antenna in the high band, and a phase delay line interconnecting both dipoles with a pair of output terminals to bring the induced currents of both units arriving at said terminals in additive in-phase relation for both bands.

3. An antenna for receiving radiation in two relatively widely spaced frequency bands comprising a pair of center fed dipoles, the first dipole having a physical length approximating one-half wavelength at a selected frequency in the low band, means associated with the center section of said dipole alone to render only the outer ends thereof effective as half-wave antennas in the high band, the second dipole being mounted in coplanar spaced relation to the first dipole and having a physical length approximating one-half wavelength in the low band, said other dipole having means to render only the center section effective as a half-wave antenna in the high band, and phase delay means interconnecting both dipoles with a pair of output terminals to bring the induced currents arriving at said terminals from both units in additive in-phase relation for both bands.

4. An antenna for receiving radiation in two relatively widely spaced frequency bands, for example 54 to 88 megacycles and 174 to 216 megacycles, comprising a pair of substantially coplanar dipoles each of which has a physical length constituting it an effective one-half wavelength antenna for the low band, means associated with the first dipole to suppress the center section as an effective antenna at the high band while allowing the entire length of the first dipole to be effective in the low band, means associated with the second dipole to render only the center section effective as a half-wave dipole for the high band without affecting the length of the second dipole as an effective half-wave antenna in the low band, and a phase delay line interconnecting both said dipoles with a pair of output terminals to bring the induced currents arriving at said terminals into like additive phase for both bands.

5. An antenna according to claim 4 in which the said means associated with the first dipole to suppress the center section as an effective antenna at the high band comprises a conductor mounted in closely spaced parallelism with the center section of the first dipole.

6. An antenna according to claim 4 in which the said means associated with the first dipole to suppress the center section as an effective antenna at the high band comprises a conductor which is approximately one-third the length of the first dipole and is spaced from the first dipole a distance less than one-twentieth of the length of the first dipole.

7. An antenna according to claim 4 in which the second

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dipole is mounted in front of the first dipole a distance approximating one-quarter wavelength at the high band and approximately one-twelfth wavelength at the low band.

8. An antenna according to claim 4 in which the second dipole is mounted in front of the first dipole a distance approximating one-quarter wavelength at the high band and approximating one-twelfth wavelength at the low band, and said phase delay line has a delay of 180 degrees phase at the high band.

9. An antenna according to claim 8 in which said phase delay time consists of a pair of legs each formed from a rigid wire having a portion of its length coiled to form an inductive reactance and each leg having a substantially uncoiled portion with the said coiled portions relatively closely spaced to provide a capacitive shunt reactance for imparting the desired phase delay to said line.

10. An antenna according to claim 4, in which the said means associated with the second dipole comprises a portion of the second dipole at each end thereof bent back upon itself into closely spaced relation with the remainder of the unbent back length of the dipole.

11. An antenna for receiving radiation in two relatively widely spaced frequency bands, for example 54 to 88 megacycles and 174 to 216 megacycles, comprising a first center-fed dipole having a physical length to constitute it a half-wave antenna at a predetermined frequency in said low band, a conductor mounted in relatively closely spaced relation rearwardly of the center third portion of said first dipole to constitute with said center third por-

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tion a transmission line whereby the end third portions of said first dipole act as half-wave antennas at a predetermined frequency in said high band, a second center-fed dipole mounted forwardly of the first dipole at a distance approximating one-quarter wavelength at said predetermined frequency in said high band and approximately one-twelfth wavelength at said predetermined frequency in said low band, said second dipole having its ends folded back to leave approximately one-third unfolded and in substantially planar alignment with the center third of the first dipole, and a phase delay line interconnecting the center feed points of both dipoles said line having a delay of approximately 180 degrees at said predetermined frequency in said high band.

12. An antenna according to claim 11 in which a parasitically driven reflector is mounted rearwardly of the first dipole and the spacing between said reflector and said first dipole is at least ten times the spacing between said first dipole and said conductor.

13. An antenna according to claim 12 in which a parasitically driven director is mounted forwardly of the second dipole and is constituted of three co-linear spaced rods each of which has a length approximating the length of said ungapped portion of the second dipole.

14. An antenna according to claim 13 in which a second parasitically driven director is mounted forwardly of the first director.

No references cited.