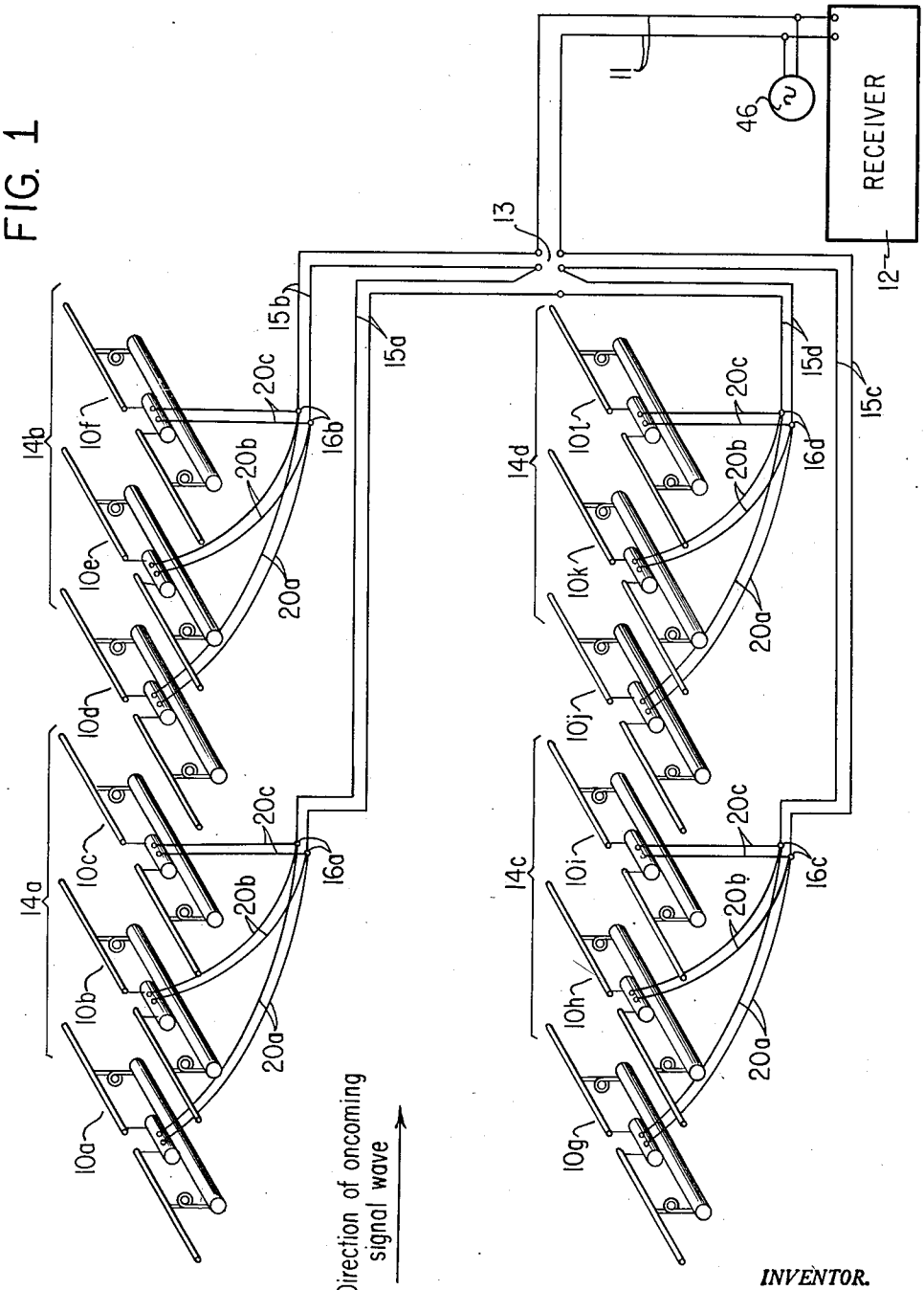
Dec. 18, 1951 E. G. HILLS 2,578,973

ANTENNA ARRAY

Filed Dec. 11, 1946 3 Sheets-Sheet 1

FIG. 1



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ANTENNA ARRAY

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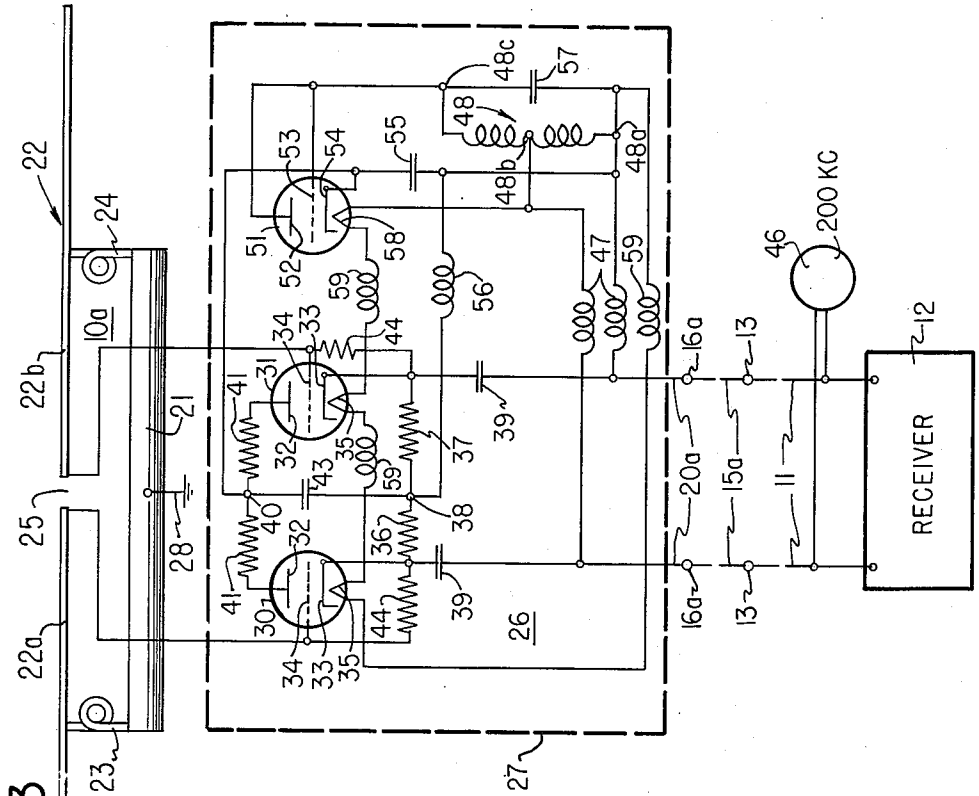


FIG. 3

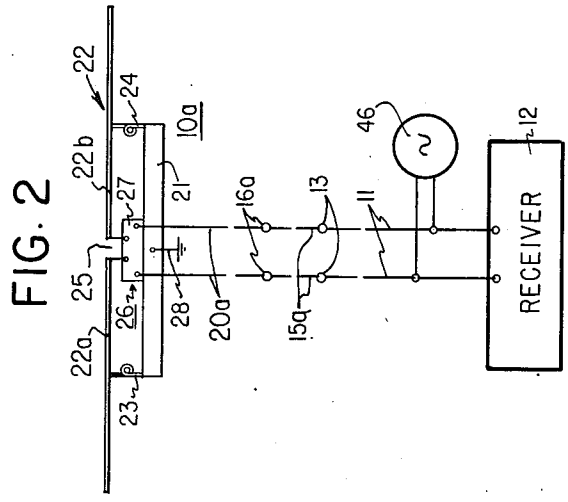


FIG. 2

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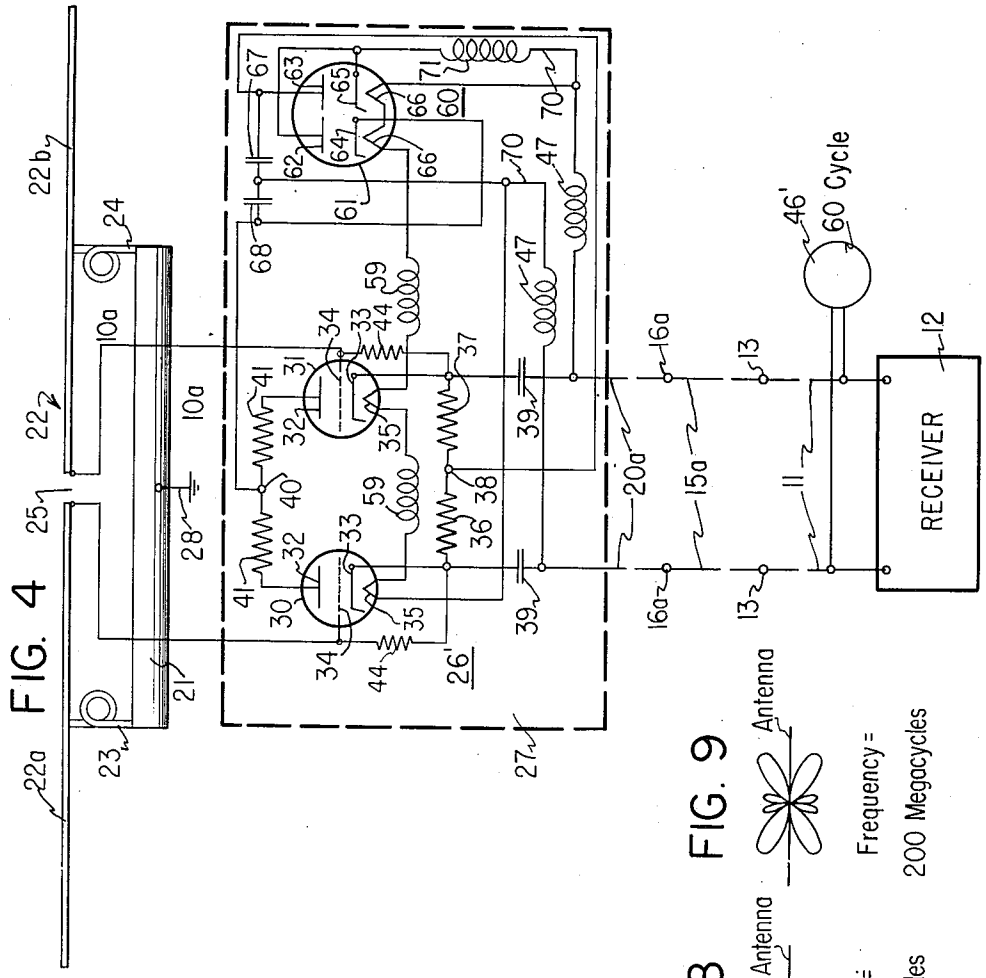


FIG. 4

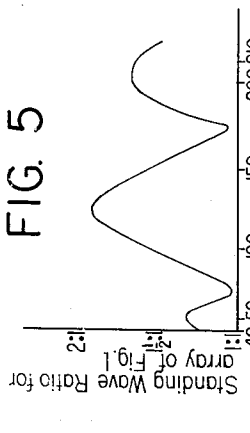


FIG. 5

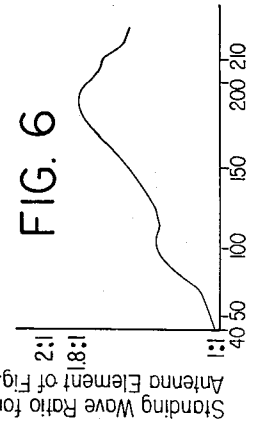


FIG. 6



FIG. 7

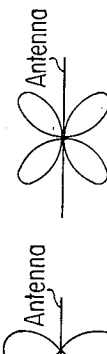


FIG. 8

FIG. 9

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UNITED STATES PATENT OFFICE

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Application December 11, 1946, Serial No. 715,487

13 Claims. (Cl. 250—20)

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The present invention relates to antennas and antenna arrays and more particularly to an antenna element as well as an omnifrequency directional antenna especially adapted for use in connection with frequency modulation and television circuits.

For both frequency modulation and television circuits, it is becoming increasingly important to employ directional antennas to concentrate transmitted power in the desired directions in the case of transmitting antennas and to receive radio frequency energy from the desired directions in the case of receiving antennas. It is a well known fact that to obtain a directive antenna arrangement, it is necessary to provide an antenna array so that the fields radiated from the elements making up the array add in some preferred direction and cancel in other directions. Heretofore whether the array has been of the broadside, end-fire, or other types, a definite limitation was involved since the directional patterns of such arrays were confined to a narrow frequency band. This is a serious limitation due to the wide bands allocated to frequency modulation and television. The reason for this limitation of existing antenna arrays which limitation causes deterioration of the array reception pattern in the case of a receiving antenna when the frequency changes is due to three factors. First, a change in frequency causes a change in the relative electrical lengths of the radiator feed transmission lines to the elements of the array. Second, a change in frequency causes a change in radiator feed point impedances of the array elements assuming the elements are isolated from each other; and third, a change in frequency causes a change in mutual impedances between radiators when placed in an array, although the effect of such change may be negligible if the spacing between the elements is relatively large.

The reasons for the deterioration of the array reception pattern set forth above can be better understood by considering a typical array such for example as a broadside array of equal currents in which the different elements which are generally dipoles or modified forms of dipoles are fed from a common transmission line junction through transmission lines, the lengths of which differ by integral multiple wave lengths. Since the open circuit voltages at the ends of these transmission lines would all be in phase if the radiating or receiving elements were disconnected, it is necessary that all of the elements present the same complex impedances to their respective lines when connected to these lines in

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order that equal in-phase currents flow in the radiators. In order that the radiator impedances be equal when arranged in the array, the elements must, of course, be in general different from each other because if they had identical impedances when isolated from the other elements, the mutual impedances between the elements when placed in the array would alter the element input impedances so that they would not in general be identical. As the frequency of operation of the array is changed, the electrical lengths of the various transmission lines change such that they no longer differ by integral multiples of wave lengths even if at the new frequency the element or dipole input impedances were still identical. Consequently, the currents would have changed because of this change in relative electrical lengths of the transmission lines with the resulting deterioration of the array reception pattern. Actually, however, the radiator input impedances do change as a result of two effects with resulting aggravation of the radiator current non-uniformity. As was mentioned above, one effect is that the impedances of the radiators if isolated in general change with frequency, and the other is that the mutual impedances between the radiators when placed in the array change with frequency.

With reference to the change in electrical lengths of the various transmission lines connected to the elements of the array, it will be understood that if the total electrical length of the composite paths that the signal must travel from the distant transmitting source through free space to the various elements of the receiving antenna array and then to the receiver, which path includes free space as well as the transmission lines, are made the same regardless of what path the signal is considered as traveling by way of, then the change in relative electrical lengths of the radiator feed transmission lines with frequency will exactly compensate for the change of relative phase of voltage induced in different dipoles by the arriving wave such that all voltages arrive at the receiver in phase for maximum signal. For the case of a broadside array where the signal path through free space is the same for all of the elements of the array this would merely mean the making of all of the transmission lines from the receiver input terminals to each element of the array of the same electrical length, that is, signal length as contrasted with phase length. Heretofore it was common practice to make the phase lengths the same so that different paths varied by integral

wave lengths. It is obvious that for different frequencies the wave lengths will vary so that by maintaining the same phase lengths would make it work properly only at one frequency and for all other frequencies the phase lengths would vary. The distance the signal travels or in other words the length of the signal path should be the same for each element of the array, when the composite path of the signal through free space and through the transmission line is converted to a constant velocity path.

Antennas have been constructed wherein the feed point impedance of the isolated elements remains constant with changes in frequencies. Examples of such antennas are those using conical elements. As has been pointed out above, however, even if the feed point impedances of the isolated elements of the array remain constant with changes in frequency, when these elements are placed in the array, the mutual impedances between the elements of the array change with frequency. It has been suggested that the effect of the mutual impedances between the elements of the array changing with frequency can be minimized by placing the elements of the array so far apart in space that the mutual impedances existing between them are negligible. This spacing would have to be of the order of three wave lengths at the lowest operating frequency of the array and obviously this would be very wasteful of space with the result that an entirely impractical antenna for general use would obtain.

It is an object of the present invention to provide a new and improved antenna arrangement for use in connection with television or frequency modulation circuits in which a directional reception pattern is obtainable which does not substantially change over a wide band of frequencies.

It is another object of the present invention to provide a receiving antenna array in which the directive reception pattern does not substantially change with changes in frequency.

Still another object of the present invention is to provide a new and improved omnifrequency directional antenna array for radio receivers in which changes in frequency have substantially no effect on either the mutual impedances of the elements of the array, or the impedances of the feed points of the array elements considered in an isolated condition, and the changes in relative electrical lengths of the transmission lines connecting each array element with the receiver or transmitter compensate exactly for the change of relative phase of the voltages induced in the elements of the array by the arriving wave so that all voltages arrive at the receiver in phase.

It is a feature of the present invention to provide an antenna array which has a desirable directive characteristic over a wide band of frequencies wherein the currents flowing in the various elements of the array are reduced to such low amplitudes that the effect of mutual impedances is substantially eliminated without reducing the effective efficiency of the power transmission from the receiving element to its transmission line.

It is another feature of the present invention to provide an omnifrequency directional antenna array in which a cathode follower device is associated with each element of the array, whereby the currents flowing in each element of the array may be reduced to such a low value that the effects of mutual impedances are completely eliminated and yet whereby the radio frequency energy in the case of a receiving antenna is amplified in the cathode follower circuit so that a satisfactory signal is obtained at the receiver.

It is a further object of the present invention to provide an antenna array in which the signal supplied to the receiver includes power from a suitable source other than that supplied by the electromagnetic radio wave.

Still a further object of the present invention is to provide a new and improved antenna comprising a modified dipole.

It is another object of the present invention to provide a modified dipole antenna which is inductive over a wide range of frequencies, which has a substantially constant resistance over a wide frequency range, and which radiates normal to its length with a directive pattern which has only a single lobe on each side regardless of the frequency.

Further objects and advantages of the present invention will become apparent as the following description proceeds and the features of novelty which characterize this invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the present invention, reference may be had to the accompanying drawings in which:

Fig. 1 is a schematic diagram of a typical end-fire antenna array embodying the present invention;

Fig. 2 is a view of one element of the array of Fig. 1, showing its connection in the circuit;

Fig. 3 is a circuit diagram of the antenna shown in Fig. 2 bringing out the details of the cathode follower associated therewith;

Fig. 4 is a circuit diagram similar to Fig. 3 illustrating a modification of the arrangement of Fig. 3;

Fig. 5 is a curve diagram indicating the standing wave ratio with various frequencies of the antenna array of Fig. 1;

Fig. 6 is a curve diagram similar to Fig. 5 indicating the standing wave ratio with various frequencies of the antenna element of Fig. 2; and

Figs. 7, 8 and 9 are polar diagrams showing the strength of field radiated in various directions from an ordinary dipole antenna at different frequencies.

In practicing the present invention, there is provided an antenna array made up of a plurality of elements each essentially a modified folded dipole. Associated with each dipole is a cathode follower circuit having its input connected to the feed point of the dipole. The outputs of the cathode followers of the various antenna elements are interconnected in suitable series, parallel, or series parallel arrangement so as to match a transmission line such as a 300 ohm transmission line connected to the receiver. A suitable source of power which may be either 60 cycle or a relatively high frequency alternating current is supplied to each cathode follower circuit through the transmission line. The cathode follower circuits which have a constant output impedance regardless of frequency prevent the feed point impedance of the elements of the array when considered to be isolated from each other from varying with frequency. By virtue of the arrangement, low input currents flow so that the effect of the change in mutual impedances with frequency are negligible. The alternating current power supplied through the transmission line to the cathode followers furnishes part of the signal energy received at the receiver.

For the purpose of simplifying the disclosure and the description, the omnifrequency directional antenna array of the present invention has been illustrated specifically in connection with an end-fire array connected to a television or frequency modulation receiver. It should be understood that the invention is equally applicable to various other types of antenna arrays such, for example, as the broadside, colinear and the like arrays and the particular disclosures and descriptions are by way of example only. Furthermore, each modified dipole element of the antenna array may be used separately as an antenna either with or without the cathode follower device described hereinafter.

Referring now to Fig. 1, there is illustrated an end-fire array comprising twelve modified dipole elements, each designated by the reference numeral 10 with appropriate subscripts *a*, *b*, *c*, etc. and arranged in two rows, one above the other with six in each row. The elements 10*a*, 10*b*, 10*c*, 10*d*, 10*e* and 10*f* are arranged in the upper rower of Fig. 1 while the elements 10*g*, 10*h*, 10*i*, 10*j*, 10*k* and 10*l* are arranged in the lower row. These elements 10 may be connected in series, parallel, or in a series parallel arrangement. To illustrate the invention, it is assumed by way of example that the array comprising the elements 10 is connected through a 300 ohm transmission line 11 to a receiver 12. As illustrated in Fig. 1 of the drawings the 300 ohm transmission line 11 connects the receiver 12 with a junction point 13. In order to relate the 300 ohm transmission line to the twelve element array, the elements are divided into four groups 14*a*, 14*b*, 14*c* and 14*d* of three elements each. The groups 14 are connected in series with each other at the junction point 13 through a connection of substantially zero length and to match the 300 ohm impedance of the transmission line 11 each group is connected to the series connection point 13 through a 75 ohm transmission line 15 designated by the appropriate subscript corresponding with the associated group. These 75 ohm transmission lines 15*a*, 15*b*, 15*c* and 15*d* interconnect the junction points 16*a*, 16*b*, 16*c* and 16*d* of each group 14 of three elements with the series junction point 13. It will be apparent from Fig. 1 that a plurality of parallel connected transmission lines 20 interconnect the elements 10 of each group 14 with the junction points 16*a*, 16*b*, 16*c* and 16*d* which must provide an impedance of 225 ohms each to match the 75 ohm transmission lines 15. These transmission lines 20 of each group are designated specifically as 20*a*, 20*b* and 20*c* respectively. Consequently, each antenna element 10 for the arrangement disclosed in Fig. 1 of the drawings must have a feed point impedance of 225 ohms to match the 225 ohm transmission lines 20. It should be understood that the specific values described are for the specific arrangement to match the 300 ohm transmission line 11. Various other combinations of the elements of the array might equally well be employed in which case the impedances of the transmission lines and the input impedances of the antenna elements would be different. It will be understood that the electrical path lengths must be identical between the transmitter and the receiver. The particular element of the array closest to the transmitter must have a longer transmission line path than the element farthest from the transmitter since the path of the signal through free space for the former is shorter. The differences in length of the transmission line will not be the same as the differences in length of the paths through free space since the velocity of travel of the signal through air differs from the velocity of travel through the transmission line. As illustrated in Fig. 1, the antenna element 10*a* is closer to the oncoming signal wave than the element 10*b* so that the transmission line 20*b* must be shorter than the transmission line 20*a*. Similarly the group 14*a* is closer to the oncoming signal wave than the group 14*b* so that the transmission line 15*a* must be longer than the transmission line 15*b*.

In accordance with the present invention, each element 10 of the antenna array comprises a modified folded dipole constructed in a particular manner so as to afford an inductive impedance, the purpose of which will become apparent as the following description proceeds. Referring now to Fig. 2 of the drawings, where there is illustrated the element 10*a* identical with all the other elements of the array comprising a pair of parallel conductors 21 and 22 supported in spaced parallel relationship by interconnecting conducting members 23 and 24. The conductor 22 is illustrated as made up of two sections 22*a* and 22*b* arranged in spaced coaxial end-to-end relationship with the adjacent ends separated slightly as indicated at 25 to provide the feed point for the folded dipole. As illustrated, the feed point 25 is opposite the mid-point of the conductor 21, and the conductor 22 comprising the two parts 22*a* and 22*b* is twice as long as the conductor 21. Consequently, the supporting members 23 and 24 which are illustrated as comprising a one-turn loop are connected between the respective ends of the conductor 21 and the mid-points of the conductors 22*a* and 22*b*. The sizes of the conductors 21, 22, 23 and 24 are not all the same, the reason for which will become apparent as the following description proceeds. For a particular embodiment of the present invention, the conductor 22 comprises a pair of ¼ inch brass rods having an over-all length when positioned as in Fig. 2 of the drawings of 7½ feet which is twice the length of the conductor 21 which for a particular embodiment comprises a 1 inch outside diameter brass tube. The supporting conductors 23 and 24 for the particular embodiment mentioned above comprised ¼ inch brass rods each including a 3 inch diameter one-turn loop. The feed point 25 of the modified folded dipole described is in accordance with the present invention connected by suitable means to the input of a cathode follower circuit generally indicated at 26 and to be described in greater detail hereinafter in connection with Figs. 3 and 4 of the drawings. Preferably, the cathode follower circuit of the present invention is contained within a suitable metal container 27 supported from the conductor 21 in any suitable manner. If desired the conductor 21 may be grounded as indicated at 28 so long as the ground is at the center thereof. This provides a simple means for supporting the antenna elements 10. Each one of the transmission lines 20 described in connection with Fig. 1 is connected to the output of its associated cathode follower circuit 26 within container 27 in a manner which will be described in greater detail. The electrical path from the antenna element 10*a* of Fig. 2 to the receiver 12 includes the transmission line 20*a*, junction point 16*a*, transmission line 15*a*, junction point 13 and the transmission line 11.

For the purpose of maintaining the currents flowing in each of the elements 10 of the antenna array at such low amplitudes that there is no appreciable voltage induced in any one element

by virtue of the current flowing in any other element relative to the voltage induced in any element by the incident wave being received, each receiving element 10 is terminated in an impedance much greater than the impedance at the feed point 25 of the modified folded dipole. This is accomplished in accordance with the present invention by means of the cathode follower device 26 referred to above. It is a well known fact that the input impedance of a cathode follower is very high while its output impedance is relatively low. Accordingly, the input impedance of the cathode follower device 26, shown in Fig. 3 of the drawings, is extremely high compared to the feed point impedance at 25 so long as the transit time loading does not enter into the picture. As a result, a very low current flows in the dipole or antenna element 10 since the dipole or antenna element 10 is effectively open circuited at 25 when the cathode follower 26 is inserted in the circuit. Consequently no ill effects of change in mutual impedances with change in frequency result and no deterioration of the directivity pattern of the array made up of the cathode follower antenna elements occurs.

Since a transmission line is always a pure resistance it is desirable for the antenna connected to the transmission line to also present a pure resistance for an accurate match therewith. Actually the impedance of the input or grid circuit of the cathode follower device 26 to be described in greater detail hereinafter is capacitive and it is for this reason, as was mentioned above, that the antenna element 10 is a modified folded dipole of the form described in order to have an inductive input impedance which is made possible at all frequencies in the 40 to 220 megacycle band by the supports 23 and 24, each containing the one-turn loop. Thus, an antenna element having an accurate match with a pure resistance transmission line can be obtained. The supports 23 and 24 also provide the folded dipole construction whereby the radiation resistance by virtue of the folded construction with the conductors 21 and 22 of different diameters is greatly increased, thus increasing considerably the voltage applied to the cathode follower 26. The input impedance of the cathode follower does not match the feed point impedance of the dipole itself but is substantially an infinite impedance to the line and this mismatch further produces substantially twice the voltage input to the cathode follower device 26 that would be applied if its input impedance matched that of the dipole.

Referring now to Fig. 3 of the drawings, there is illustrated a cathode follower device 26 which actually comprises two cathode followers although it will be understood that an arrangement employing a single cathode follower circuit could be used to advantage with a coaxial transmission line. As illustrated in Fig. 3, the cathode follower device 26 comprises a pair of triodes 30 and 31, each having an anode 32, a cathode 33 and a control electrode 34. Each may also be supplied with a heater element 35. The control electrodes 34 of each electron discharge valve 30 and 31 are connected respectively to the adjacent ends of the divided conductor portions 22a and 22b, this connection being at the so-called "feed point" 25 of the modified folded dipole of the present invention. The cathodes 33 of each of the electron discharge valves 30 and 31 are each connected to suitable cathode resistors 36 and 37, respectively, which resistors are connected to a common terminal 38. The output of the cathode follower circuit 26 is obtained across the serially arranged resistors 36 and 37 by means of the transmission line 20 comprising two conductors, each of which includes a suitable coupling capacitor 39. Essentially the two cathode followers are connected in series and each of the anodes 32 of electron discharge valves 30 and 31 is connected to a common terminal 40 through a suitable resistor 41 for decreasing the effect of plate-to-cathode capacity in the tubes 30 and 31. A suitable plate supply filter capacitor 43 is preferably connected across the plate-to-cathode circuits, as illustrated, interconnecting terminals 38 and 40. Also, a suitable grid-to-cathode resistor 44 may be provided for each electron discharge valve 30 and 31.

In accordance with the present invention, the transmission line 20 which has been mentioned above as a 225 ohm transmission line in addition to providing a path for the signal is also employed to supply power to the plate circuits of the cathode follower circuits 26. In accordance with a preferred embodiment of the present invention, a suitable source of 200 kilocycle alternating current indicated at 46 is provided and connected to supply power to the transmision line 20 through any suitable means. For the specific arrangement shown in Fig. 1, the power from source 46 is supplied to the cathode follower device 26 of the antenna element 10a through transmission lines 11, 15a and 20a. It will be understood that this source 46 may comprise any suitable generator such, for example, as a high frequency oscillator and this source will be associated with the receiver 12 so as to supply power to the cathode followers 26 associated with all of the antenna elements making up the array. Alternating electrical energy of two hundred kilocycle frequency is chosen since this energy can readily be rectified to a direct current potential without any filter problem and in addition, any transformer required for stepping up the voltage is relatively small and inexpensive compared to what would be the case if 60 cycle power were employed.

In accordance with the present invention the 200 kilocycle alternating current energy supplied to the transmission line 20 is conducted through a pair of radio frequency choke coils 47, which readily pass 200 kilocycle energy but prevent the signal energy from passing, to an auto transformer 48 having input terminals 48a and 48b and output terminals 48a and 48c. The output terminals 48a and 48c are connected to a suitable rectifier 51 illustrated as a triode having its plate 52 and its control electrode 53 connected in parallel. The cathode 54 is connected through a suitable capacitor 55 and a choke coil 56 to the terminal 38 of the cathode follower device 26, while the other terminal of the capacitor 55 is connected to the terminal 40. In other words, the direct current voltage appearing across capacitor 55 is supplied to the plate-to-cathode circuits of the cathode follower device 26 comprising the electron discharge valves 30 and 31 arranged in series. A suitable capacitor 57 may be connected across the output terminals 48a and 48c of the auto transformer 48 if desired. For the purpose of supplying power to the heater elements 35 of electron discharge valves 30 and 31 and the heater element 58 of electron discharge valve 51 suitable taps may be provided on auto transformer 48. As illustrated in Fig. 3,

this power is obtained from taps 48a and 48b and the heaters 35 and 58 are preferably connected in series with suitably interspersed radio frequency choke coils 59.

It will be understood that the constants of the cathode follower circuit 26 will determine the magnitude of the current which must be supplied thereto from the 200 kilocycle source. In accordance with the present invention, the voltage of the 200 kilocycle source is then chosen such that with reference to the current supplied to the cathode follower circuit 26 there is an impedance presented which matches the impedance of the transmission line 11, or in other words, for the values referred to above has an impedance value of 300 oms. Because of this, the transmission line is matched and it will not de-tune the source no matter what length of 300 ohm transmission line the user of the antenna sees fit to connect between the antenna and his receiver. In other words, the 300 ohm transmission line is matched at the antenna, both for the signal frequency and for the 200 kilocycle power frequency.

From the above discussion, it will be apparent that with the arrangement described a high voltage is obtained from the cathode follower which is fed to a transmission line of lower impedance than the dipole impedance so actually more power or signal energy is supplied from the antenna elements to the transmission line 11 than was taken out of the radio wave received at the antenna. Part of this power is supplied by the 200 kilocycle generator 46. The voltage maintained at the output of the cathode follower circuit 26 is substantially the same or perhaps slightly lower than the voltage at the input thereof. It will furthermore be apparent that the cathode follower circuit 26 associated with each antenna element 10 will present a constant impedance. It is well established that the internal or source impedance presented by a cathode follower circuit is the reciprocal of the transconductance of the tube or tubes employed which is independent of frequency. The varying impedances of the modified folded dipole elements connected to the cathode follower devices 26 have no effect and essentially a constant output impedance for all frequencies intercepted by the antenna is provided with the result that the antenna is a very satisfactory directional antenna for all frequencies.

The operation of the antenna array of the present invention will be apparent in view of the detailed description included above. By virtue of the use of the cathode follower device 26 the output impedance of all the cathode follower circuits remains constant and independent of frequency. Actually, as was mentioned above, the output impedance of a cathode follower is equal to the reciprocal of the transconductance of the tube employed and preferably a tube of relatively high transconductance is employed such as the 6C4 or the like. Due to the fact that the high input impedance of the cathode follower causes very low currents to flow in the antenna, the effect of mutual impedances is negligible even at close spacing of the antenna elements. The signal power supplied to the receiver through the transmission line is partially the signal intercepted by the antenna amplified by the power supplied to the cathode follower circuit from the 200 kilocycle generator.

At frequencies in the 176 to 216 megacycle television band, the input loading of the electron discharge valves 30 and 31 becomes appreciable

and in this case, it is necessary partially to match the impedance of the modified folded dipole to the cathode follower input impedance in order to increase the voltage on the grid of the tube while still having the impedance of the modified folded dipole low enough with respect to the tube input impedance that large enough dipole currents do not flow to cause changes in the mutual impedances of the elements in the array. In the lower television band, this factor is unimportant, i. e., the 44 to 88 megacycle band.

Although in the arrangement described thus far 200 kilocycle alternating current energy is supplied through the transmission line to the antenna elements, it will be understood that ordinary 60 cycle energy might be supplied to the cathode follower circuits of each antenna element. In Fig. 4 of the drawings, there is illustrated an antenna element similar to Fig. 3 wherein the power supplied to the cathode follower circuit 26' is 60 cycle energy. The corresponding parts of Fig. 4 are designated by the same reference numerals as in Fig. 3. The electron tubes 30 and 31 are identical in the two arrangements but the 60 cycle energy is supplied from a source 46' through the choke coils 47 to a voltage doubler generally indicated at 60. Such a voltage doubler is required since the Underwriters have limited the 60 cycle voltage that can be supplied to antenna apparatus which is to be connected up by members of the public to 25 volts. The voltage doubler circuit comprises preferably a twin diode 61 having a pair of anodes 62 and 63, respectively, a pair of cathodes 64 and 65, respectively, and a pair of heaters 66. The two rectifying paths through the twin diodes 61 are connected so that the path including anode 63 is in series with a capacitor 67, while the path including the anode 62 is in series with a capacitor 68. The output of the voltage doubler rectifier arrangement is obtained across the capacitors 67 and 68 in series thus producing the voltage doubling action. The input circuit designated at 70 includes the choke coil 71 and the two rectifying paths referred to above which will alternately pass the alternate half cycles of the alternating current wave. The 60 cycle power supplied through the choke coils 47 is also supplied directly to the heater elements 35 and 66 connected in series with suitable choke coils 59 interposed therebetween. The operation of the arrangement disclosed in Fig. 4 of the drawings will be obvious to those skilled in the art and no further discussion thereof will be included herewith.

It will be understood that a source of direct current potential may be fed directly to the cathode follower circuits in any suitable manner or a separate supply line for the power to the cathode followers may be employed rather than using the transmission line itself. However, the arrangements described above are believed to be preferable for reasons which are obvious.

It will be understood by those skilled in the art that the standing wave ratio of an antenna is effectively a measure of mismatch between the antenna and the associated transmission line connected thereto. In Fig. 5 of the drawings there is shown the standing wave ratio for the antenna array of Fig. 1 showing that it is very satisfactory particularly over the television band. In Fig. 6 there is illustrated the standing wave ratio for one antenna element of the array as

for example the antenna element of Fig. 2 of the drawings.

It is a well known fact that the reception pattern of the ordinary dipole antenna varies greatly with frequency. In Figs. 7, 8 and 9 are shown the reception patterns of a dipole antenna with the various frequencies specifically indicated at 50 megacycles, 100 megacycles, and 200 megacycles, respectively. Such a change in the reception pattern of the modified dipole of the present invention with frequency does not occur and for all frequencies the polar diagrams of the reception pattern are substantially identical and comprise a single lobe on each side of a line each lobe being substantially a circle tangent to said line, and the direction of radiation of said modified dipole being normal to its length.

While the circuit parameters and the type of electron discharge valves employed in the antenna circuits of the present invention may be chosen to meet the requirements of any particular installation, the following circuit specifications have been found entirely satisfactory for use in a typical installation operable over the television band from 40 to 216 megacycles.

Circuit Component	Description
Transmission Line 11	300 ohm coaxial line.
Transmission Lines 14	73 ohm coaxial lines.
Transmission Lines 20	225 ohm coaxial lines.
Conductor 21	1" outside diameter brass tubing 3¾ ft. long.
Conductor 22	¼" brass rod 7½ ft. long with gap in the middle.
Supports 23 and 24	¼" brass rod including 3" one-turn loop.
Electron discharge valves 30 and 31.	6C4.
Resistors 36 and 37	300 ohms.
Capacitors 39	100 $\mu\mu$f in Fig. 3; 1500 $\mu\mu$f in Fig. 4.
Resistors 41	300 ohms in Fig. 3; 200 ohms in Fig. 4.
Capacitor 43	.001 μf.
Resistors 44	51,000 ohms.
Choke coils 47	5 microhenries.
Electron discharge valve 51	6C4.
Capacitor 55	.01 μf.
Capacitor 57	210 $\mu\mu$f.
Choke coils 56	5 microhenries.
Electron discharge valve 61	12H6.
Capacitor 67	30 μf.
Capacitor 68	30 μf.
Choke coil 71	5 microhenries.

In view of the description included above, it will be apparent that there has been provided an antenna array which is directional in character and which directivity pattern will not vary with changes in frequency so that it is satisfactory over a wide range such as is employed in the frequency modulation and television bands. By employing the cathode follower arrangement described above, the impedances of each element of the array remain constant regardless of frequency changes. In addition to that, the high input impedances of the cathode followers cause relatively low dipole currents to flow so that the effects of mutual impedances with change in frequency is negligible and a very compact antenna with close spacing of the elements of the array may be obtained. Since the antenna and the transmission line can be perfectly matched with the arrangement proposed above to provide perfect termination, the transmission line acts as a 1:1 transformer and is wholly independent of frequency so the lengths of the transmission line are immaterial.

Also with the modified dipole of the present invention there is provided an antenna which is inductive over a wide range of frequencies and which radiates normal to its length with a directive pattern which has only a single lobe on each side regardless of frequency.

While the present invention has been shown and described in connection with certain specific embodiments, it will, of course, be understood that the invention is not limited thereto since it is apparent that the principles herein disclosed are susceptible of numerous other applications, and modifications may be made in the circuit arrangement and in the instrumentalities employed without departing from the spirit and scope of the present invention as set forth in the appended claims.

What is desired to be secured by Letters Patent of the United States is:

1. In combination with an antenna for a wave signal receiver which has a constant impedance regardless of changes in frequency of the received signal comprising a radiating element, a cathode follower circuit including a pair of electron discharge valves having input and output circuits, means for connecting said input circuit to said element, a transmission line interconnecting said output circuit with said receiver, a source of high frequency alternating current electrical energy for the output circuit of said electron discharge valves, and means including said transmission line for interconnecting said source and said output circuit, said transmission line being matched with said antenna for the wave signal energy as well as said high frequency electrical energy.

2. An antenna for a wave signal receiver which has a constant impedance regardless of changes in frequency of the received signal comprising a radiating element, a cathode follower circuit having an input and an output circuit, means for connecting said input circuit to said element, a transmission line connected to said output circuit, a source of low frequency alternating current electrical energy for said output circuit, means including said transmission line for interconnecting said source and said output circuit, and means for stepping up the potential of said source at said cathode follower circuit whereby said transmission line may be maintained at a low potential.

3. A folded dipole antenna comprising a first relatively short conductor, a second relatively long conductor including two colinear parts spaced from each other, and supporting means connected to the ends of said first conductor and said parts of said second conductor, said supporting means having looped conductor portions therein to afford reactive impedance connections between said conductors, each of such looped conductor portions having extremities which are positioned close to each other substantially in alignment with said short and long conductors, and having parts immediately adjoining such extremities which diverge from each other respectively to points of maximum separation on opposite sides of the loop.

4. A folded dipole antenna comprising a first conductor adapted to be supported on a mast, a second conductor including two colinear parts spaced from each other, and supporting means secured to the ends of said first conductor and to said parts of said second conductor for supporting said parts, said supporting means being single turn loops which form reactive impedance connections between said conductors, each of said loops having extremities which are postioned close to each other substantially in alignment with said first and second conductors, and having parts immediately adjoining such extremities diverging from each other respectively to points of maximum separation on opposite sides of the loop.

5. A folded dipole antenna comprising a first conductor of relatively large diameter, a second conductor comprising two colinear parts of relatively small diameter spaced from each other, and supporting means secured to the ends of said first conductor and to said parts of said first conductor for supporting said parts from said first conductor, said supporting means being in the form of single turn loops which provide reactive impedance connections between said conductors, each of said loops having extremities which are positioned close to each other and parts immediately adjoining such extremities which diverge from each other respectively to points of maximum separation on opposite sides of the loop.

6. An antenna which has a directional pattern substantially independent of frequency throughout a wide range of frequencies, such antenna comprising a folded dipole having a pair of substantially parallel spaced conductors, and a pair of conductors positioned in proximity to and interconnecting said spaced conductors, each of said interconnecting conductors having a continuous loop therein of such configuration that the two extremities of the loop are positioned close to each other substantially in alignment with said spaced conductors, while the portions of the loop immediately adjoining such extremities diverge from each other respectively to points of maximum separation on opposite sides of the loop.

7. An antenna which has a directional pattern substantially independent of frequency throughout a wide range of frequencies, such antenna comprising a folded dipole having a pair of substantially parallel spaced conductors, and a pair of rigid conductors positioned in proximity to and interconnecting said spaced conductors, each of said interconnecting conductors having a loop therein which is inductive over at least a large portion of said wide range of frequencies, with the opposite extremities of said loops being disposed close to each other in alignment with said spaced conductors, while the portions of the loop immediately adjoining such extremities diverge from each other respectively to points of maximum separation on opposite sides of the loop.

8. An antenna which is inductive throughout a wide range of frequencies, such antenna comprising a folded dipole having a pair of substantially parallel spaced conductors, and a pair of conductors interconnecting said spaced conductors, each of said interconnecting conductors having a length substantially greater than the spacing between said parallel spaced conductors and including an inductive loop positioned in proximity to said spaced conductors for determining in part the directional characteristics of said dipole, said loop having a substantial amount of inductive reactance over at least a large portion of said wide range of frequencies.

9. An antenna which has a directional pattern substantially independent of frequency throughout a wide range of frequencies, such antenna comprising a folded dipole having a pair of substantially parallel spaced conductors, one of said conductors being longer than the other of said conductors, and a pair of conductors interconnecting said spaced conductors at the ends of the shorter conductor and intermediate the ends of said longer conductor, each of said interconnecting conductors having a loop therein which is primarily inductive over at least a large portion of said wide range of frequencies and which is

positioned in close proximity to said spaced conductors to determine in part the directional characteristics of said dipole.

10. An antenna which has a directional pattern substantially independent of frequency throughout a wide range of frequencies, such antenna comprising a folded dipole having a pair of substantially parallel spaced conductors, one of said conductors comprising two colinear parts spaced from each other, and a pair of conductors interconnecting said spaced conductors being connected intermediate the ends of said colinear parts and at the extremities of the other of said spaced conductors, each of said interconnecting conductors having a loop therein which is primarily inductive over at least a large portion of said wide range of frequencies and which is positioned in proximity to said spaced conductors to determine in part the directional characteristics of said dipole.

11. An antenna array for a wave signal receiver comprising a plurality of antenna elements, a plurality of transmission lines connected to said receiver, and means for individually connecting said antenna elements to said transmission lines having high impedance input circuits connected to said elements and low impedance output circuits connected to said transmission lines, said transmission lines being of unequal lengths, and said antenna elements being arranged at unequal distances from the wave signal source, the elements closer to the wave signal source having longer transmission lines than do the elements farther from the wave signal source, whereby the differences in the electrical lengths of said transmission lines compensate for the differences in the phases of the voltages induced in the various antenna elements by the arriving wave signal so that all wave signal voltages arriving at the receiver through the various transmission lines are substantially in phase.

12. An antenna which has a directional pattern substantially independent of frequency throughout a wide range of frequencies, such antenna comprising a folded dipole having a short relatively thick conductor and a long relatively thin conductor in parallel spaced relation to each other, said long conductor being interrupted at its mid-pjoint, and a pair of conductors being connected intermediate the ends of said long conductor and interconnecting said spaced conductors at opposite ends of said short conductor, each of said interconnecting conductors having a loop therein which is primarily inductive over at least a large portion of said wide range of frequencies and which is disposed in proximity to said spaced conductors to affect the directional characteristics of said dipole.

13. A folded dipole antenna comprising a pair of spaced conductors, and a pair of rigid conductors interconnecting said spaced conductors and maintaining the spacing thereof fixed, each of said interconnecting conductors having a length substantially greater than the spacing of said pair of conductors and having formed therein a continuous loop which is inductive over a wide range of frequencies and which is disposed in proximity to said spaced conductors for determining in part the directional characteristics of the antenna at various frequencies.

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