May 26, 1942. L. J. McKESSON 2,283,938

ANTENNA SYSTEM

Filed Jan. 20, 1940

Fig. 1

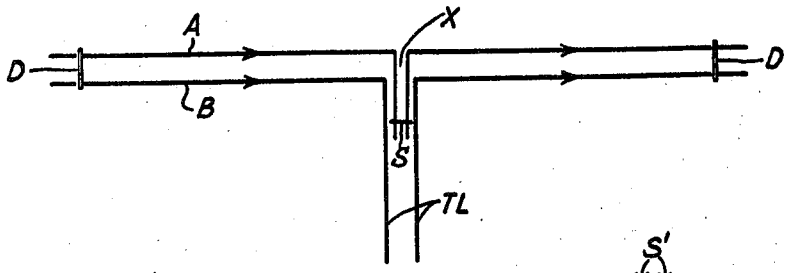


Fig. 2

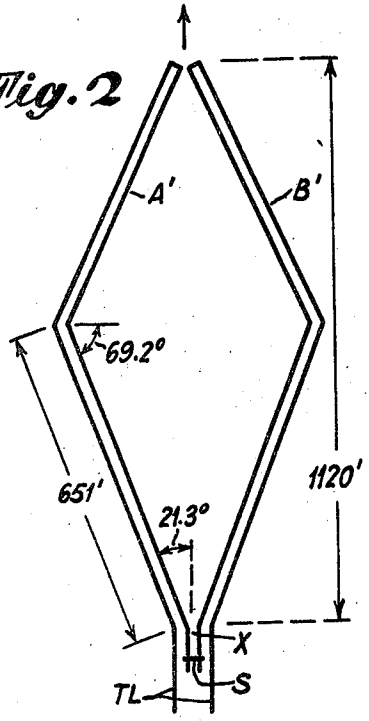


Fig. 3

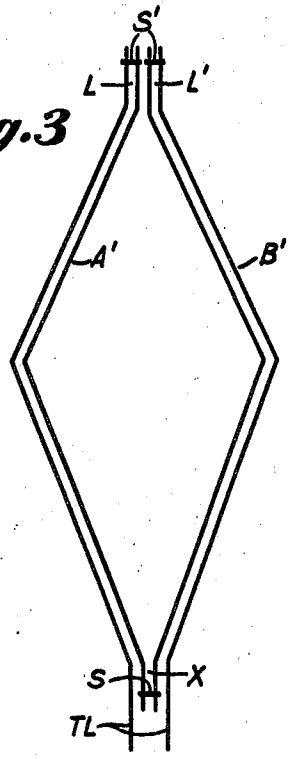
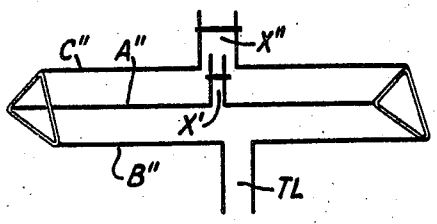


Fig. 4



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ANTENNA SYSTEM

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14 Claims. (Cl. 250—33)

The present invention relates to antennas, and more particularly to antennas for use with wide band transmission and reception.

An object of the present invention is to provide an antenna system which will have an extremely broad tuning range when directly connected to a transmission line of ordinary impedance characteristic (for example a two-wire line having impedances from 300 to 600 ohms, or a pair of concentric lines having less impedance). Stated in another way, it is desired to provide such an antenna which when directly connected to the transmission line has a flat impedance versus frequency characteristic over a broad range, as seen looking toward the antenna from the transmitter or receiver terminals.

Another object is to provide an antenna system which requires no special impedance matching circuit between the antenna and the feeder line in order to match the surge impedance of the line to the impedance of the antenna.

A further object is to provide an arrangement for controlling the characteristic of an antenna, either its directional characteristic or its characteristic input impedance, or both, without changing the physical configuration or the dimensions of the antenna.

A further object is to provide means for obtaining any desired impedance value at the input terminals of a transmitting antenna or the output terminals of a receiving antenna. This object is applicable to conditions where no transmission line is used or where a transmission line is used and it is not necessary or desirable to match its surge impedance.

A still further object is to provide means for changing or improving the radiation characteristics of all types of antennas whether of the so-called short dipole type or of long wire type such as the V or rhombic type in which the radiator lengths may be any number of wavelengths or any number of wavelengths plus any fraction of wavelengths long.

In brief, the present invention comprises a folded type of antenna having two or more parallel or approximately parallel radiating elements interconnected at their ends and spaced relatively closely to each other with respect to the length of the operating wave. A transmission line is directly connected to one of the radiating elements, while there is provided in series with another radiating element of said antenna an adjustable impedance for varying the directional properties and/or characteristic impedance of the antenna.

According to one embodiment of the present invention there is provided a multiple dipole antenna whose component elements are effectively arranged in parallel, one of whose elements is fed at the center while another element has an adjustable impedance connected in series with its center portion. Although it has just been stated that the component elements of the multiple dipole are effectively in parallel, it should be understood that by the term "effectively" it is deemed that all the dipole elements radiate in parallel or receive in parallel (depending upon whether the antenna is used for transmission or reception), while in practice from a direct current standpoint the dipole elements may, if desired, be actually connected in series, which would be the case where only two dipole elements are employed to constitute an antenna.

According to another embodiment of the invention there is provided a rhombic or diamond antenna composed of two diamond-like arrangements disposed approximately parallel and adjacent to each other and spaced apart relatively closely with respect to the length of the operating wave. These two diamond structures are arranged in series from a direct current standpoint, one being connected to a transmission line while the other has an adjustable impedance connected in series with its center portion.

One advantage of the antenna systems of the present invention is that there is obtained a flat impedance versus frequency characteristic over a broad range without the use of the usual impedance matching circuits between the antenna and the transmission line.

A more detailed description of the invention follows in conjunction with a drawing wherein Figs. 1 to 4, inclusive, illustrate different embodiments of the present invention. Throughout the figures the same reference numerals are used to designate the same or similar parts.

Referring to Fig. 1, there is shown a multiple dipole comprising two conductors A and B of substantially equal over-all length whose ends are connected together by showing wires or bars D. Conductor B is shown broken at its center for connection to a suitable transmission line TL, in turn extending to a suitable transmitter or receiver, not shown. Conductors A and B are closely spaced from one another relative to the length of the operating wave. Assuming that conductors A and B are each one-half wavelength long, it will be apparent that the currents flowing in the two conductors will be in the same direction in space; although in the opposite direction in the antenna circuit due to phase reversal at the ends. The arrows indicate the direction of current flow in the conductors. Consequently, the arrangement will be almost identical in its radiation characteristic with that of a single wire half wave dipole antenna. Because of the fact that the two conductors A and B of the multiple dipole are arranged as shown, the current in each of the wires will be very

nearly one-half of the total current. If we assume that this same total current is employed in a single wire dipole antenna one-half wavelength long, it will be evident that the antenna of the invention (Fig. 1) will provide a radiation resistance which is equal to four times the radiation resistance of the single wire dipole, thus providing a terminal impedance for the antenna which may approximate or equal the impedance of the transmission line without the use of any special impedance matching circuit between the antenna and the transmission line. The antenna of the invention, it has been found, provides an extremely flat impedance versus frequency characteristic over a broad range.

In the mid portion of the dipole radiating element A there is shown connected in series therewith an adjustable impedance X in the form of a section of a two-conductor line short circuited by a sliding bar S which is movable over the length of the conductors of the section. By moving short-circuiting bar S, it is possible to vary the phase relations of the current in conductor A with respect to the current in conductor B, thus varying the directional properties of the antenna and the characteristic impedance of the antenna at the terminals to which the transmission line TL connects. It has been found in practice that the adjustable impedance X serves to vary the radiation pattern from the antenna system in the desired fashion merely by adjustment of the short circuiting cross-bar S. The impedance X is merely typical of any network which may be employed, such as a resistor, a capacitor, or an inductance coil, or any combination of these elements. While the above discussion refers to the impedance X as a finite value, it is intended that it can have any value from zero to infinity. For zero value, the conductor A will be continuous and for infinite value, it will be open-circuited at its center. From what has been said before it will be seen that the invention provides a means for changing the directional characteristics of the antenna system without changing its physical length or location, and also provides a means for changing the terminal impedance of the antenna to a value which will match the surge impedance of the transmission line without the need for the use of the usual terminal impedance matching circuits. In effect, the antenna of Fig. 1 can be looked upon as a folded-up dipole antenna or bipolar antenna having a plurality of interconnected radiating elements each of which has two poles of opposite instantaneous polarity. The currents in the conductors A and B will be of standing wave form; that is, there will be substantially only progressive waves moving on the wires in opposite directions when using the type of impedance X shown in the drawing. If the impedance X is a pure resistance, there will be obtained a traveling wave effect which will be a maximum in the case of an antenna conductor whose current distribution is such that there is a maximum of current at the location of the adjustable impedance. Due to the close spacing of the conductors A and B, however, with the consequent mutual interaction therebetween, there will always be some reflected or standing waves on the wires of the antenna.

Referring to Fig. 1 again, it will be noted that the impedance X is shown as being coupled to the transmission line TL. This coupling can be made variable and is made use of in order to obtain desired phase and current values in the wires A and B and to obtain a broad frequency characteristic for both the antenna and transmission line.

In practice, the over-all length of the antenna of Fig. 1 may vary so as to be any desired length. Also, the short circuit connection D, D on the outer ends of conductors A and B need not be at the extreme end of the elements. If connected at some distance from the end, the impedance of the antenna system will have a different value from that when the end extremities are connected. This property makes it possible to vary at will the impedance of the system and also to adjust its frequency band width over which its impedance remains essentially constant.

Fig. 2 shows an antenna of the rhombic or diamond type embodying the principles of the invention. In effect, the antenna of Fig. 2 comprises two diamonds A' and B' disposed parallel to and adjacent to each other and interconnected at their ends in the same manner as the conductors of Fig. 1. These diamonds are closely spaced relative to the length of the operating wave. Looking at it another way, it will be obvious that the system of Fig. 2 is similar to that of Fig. 1, if we are to consider each half of each of the conductors A and B of Fig. 1 as a conductor bent into the form of a V. Thus each of the two arms of the radiating element B of Fig. 1 becomes a V bent at its center, both V's arranged in the form of a diamond B' shown in Fig. 2. Similarly, both arms of conductor A of Fig. 1 separated by the adjustable impedance X becomes two V's separated by the impedance X at its center and arranged in the form of another diamond A' shown in Fig. 2. Both diamonds A' and B' are connected together at their ends by straps in the same manner as the conductors A and B of Fig. 1 are connected together. The diamonds A and B are each in effect composed of two halves or V's, each of which has an instantaneous polarity opposite to that of the other V of the same diamond. It will thus be seen that each bipolar or dipole radiating element of Fig. 1 becomes a bipolar or dipole element in Fig. 2, but with a somewhat different physical configuration. The diamonds or rhombic antenna elements A' and B' can be placed above or within one another.

In the operation of the antenna of Fig. 2, the variable impedance X, by means of its short-circuiting bar S, can be made to change the radiation characteristic of the antenna system so as to provide a more or less unidirectional or bidirectional effect, as desired. In the one embodiment actually tried out in practice with the dimensions and angles approximately as illustrated in Fig. 2 and using the frequency of 4540 kilocycles (wavelength of 66 meters), there was obtained a ratio of front to back radiation of approximately 12 to 1 in power. With the arrangement shown and when adjusted for maximum forward radiation in the direction of the arrow, the characteristic impedance of the antenna was such that it approximated the surge impedance of the transmission line TL. The antenna of Fig. 2 is operable over a wide band of frequencies and will provide an extremely flat impedance versus frequency characteristic over this band.

Referring to Fig. 3, there is shown an antenna which is substantially identical with the antenna of Fig. 2, except that the interconnecting elements between the ends of the two

diamonds A' and B' here take the form of adjustable impedance loops L and L' instead of the direct connecting straps of Fig. 2. Loops L and L' are in the form of sections of transmission line and are provided with slidable cross-bars S' which are movable over the lengths of the conductors of the loops to short-circuit any desired length of the loop. The loops L and L' are comparatively closely spaced and being of opposite instantaneous polarities there will be no radiation into space from this part of the antenna. In Fig. 3 there is provided the same adjustable impedance X as is provided in Fig. 2 and for the same purpose. The radiation characteristics and the characteristic impedance of the antenna of Fig. 3 can be changed not only by a variation in the adjustable impedance X but also by variations in the effective lengths of the adjustable loops L and L'. Where the loops L and L' are adjusted for this purpose, both should be adjusted simultaneously in the same direction and to the same extent in order to maintain the balance of the system. In one embodiment tried out in practice following the configuration of Fig. 3, the adjustable impedance X took the form of a lumped resistor, but tests proved that the antenna with the lumped resistor for X to be inferior, so far as forward radiation is concerned, to antennas having the short-circuited line section for the adjustable impedance in the manner indicated in the drawing. Hence, when using the system of Figs. 2 and 3 it is preferred that the impedance X not be in the form of a lumped resistor, although it should be distinctly understood that the antenna system of Fig. 3 using the lumped resistor is operative in accordance with the principles of the invention.

It has been described above that an antenna of the type shown in Fig. 1 can be employed to obtain an impedance transformation ratio of 4 to 1 which will be achieved when the overall length of the conductors A and B are each one-half wavelength and the adjustable impedance X is such as to be of minimum value. Other impedance transformation ratios can be obtained which depart from the 4 to 1 ratio of Fig. 1 by varying the length of conductor A by means of a change in position of the cross-bar S of the variable impedance X. Where greatly different impedance transformation ratios are desired than 4 to 1, it is possible to use an arrangement such as is shown in Fig. 4 to obtain an impedance ratio of approximately 9 to 1. The antenna of Fig. 4 is composed of three dipole elements A'', B'' and C'' spaced along the sides of a triangle, the individual conductors of which are each one-half wavelength long and each take approximately one-third of the total current. The triangle may or may not be equilateral in form. Conductors A'' and C'' are respectively provided at their centers with adjustable impedances X' and X'' for varying the phase relations of the current in these conductors with respect to the current in the other conductors. The adjustable short-circuiting cross bars of these variable impedances provide variations in the effective lengths of the conductors containing these adjustable impedances with a consequent variation in the impedance transformation ratio of the antenna. These adjustable impedances may, if desired, be of the lumped impedance form instead of the uniformly distributed constant type of impedance. The conductors A'', B'' and C'' are, like the conductors in the previous figures, closely spaced from one another with respect to the length of the operating wave. These conductors are not limited to a triangular form but may, if desired, be placed in the same plane, either vertically, horizontally or at any plane to the horizontal.

It should be distinctly understood that the invention is not limited to the precise arrangements illustrated in the drawing and described in the specification, since various modifications may be made without departing from the spirit and scope of the invention. For example, the antennas illustrated in the figures may have more radiating elements added to them in accordance with the principles hereinabove outlined, thus providing further impedance transformation ratios. Where four radiating elements are employed, there will be obtained an impedance transformation ratio of 16 to 1, and by varying the value of the adjustable impedance it is possible to obtain slight departures from this particular impedance transformation ratio.

The above descriptions refer to the conductors A, B and C as being closely spaced from one another with respect to the length of the operating wave. It should be distinctly understood that the term "closely" spaced does not limit the spacing to any particular value. In practice, this spacing may be any value from about one hundredth or less of the operating wave to spacings up to one-half of the operating wave.

What is claimed is:

1. A bipolar antenna system comprising in combination two wire elements directly connected together at their respective ends, said wire elements being rectilinear, substantially parallel to each other and located close to each other compared to the shortest wavelength employed, one of said elements being adapted to be fed with current in its middle part, and an impedance connected in series with the middle part of the other of said wire elements, said impedance being calculated and adjusted to have a value to allow currents to flow in the bipolar elements with a desired phase relationship, said antenna system being characterized by its substantially constant radiation characteristics over a wide range of wavelengths.

2. A directional aerial system constituted by two similar conductors connected together at one of their ends and arranged substantially parallel to each other and spaced apart to an extent which is very small with respect to the shortest wave to be handled by said system, an impedance substantially equal to the characteristic impedance of said two conductors for terminating the end of one of said conductors remote from the connected end, whereby said conductors are traversed by progressive waves, a feeder connected to the other of said two conductors remote from the connected end, said two conductors being so close together that the aerial system is characterized by its substantially constant radiation characteristics over a wide range of wavelengths.

3. An antenna system comprising a conductor having a pair of separated arms, another conductor arranged parallel to said first conductor and closely spaced therefrom, a transmission line directly connected to the adjacent ends of said pair of arms, and means for connecting said arms to said other conductor at points removed from said adjacent ends, said other conductor having a lumped impedance located substan-

tially in the center thereof connected electrically in series relation thereto.

4. An antenna system comprising a pair of rhombic antennas having corresponding elements closely spaced to one another relative to the length of the operating wave, a feeder system connected to one rhombic antenna at one apex, and connections from the opposite apex of said one rhombic to the adjacent apex of the other rhombic antenna, and impedance means connected in series with said last rhombic at the apex adjacent said feeder system.

5. An antenna system comprising a pair of rhombic antennas having corresponding elements closely spaced to one another relative to the length of the operating wave, a feeder system connected to one rhombic antenna at one apex, and means for connecting said two rhombic antennas in series relation from a direct current standpoint comprising connections from the opposite apex of said one rhombic to the adjacent apex of the other rhombic antenna, and impedance means connected in series with said last rhombic at the apex adjacent said feeder system.

6. An antenna system comprising a pair of rhombic antennas having corresponding elements closely spaced to one another relative to the length of the operating wave, a feeder system connected to one rhombic antenna at one apex, and means for connecting said two rhombic antennas in series relation from a direct current standpoint comprising a pair of adjustable connections from the opposite apex of said one rhombic to the adjacent apex of the other rhombic antenna, and impedance means connected in series with said last rhombic at the apex adjacent said feeder system.

7. An antenna system comprising a pair of rhombic antennas having corresponding elements closely spaced to one another relative to the length of the operating wave, a feeder system connected to one rhombic antenna at one apex, and connections from the opposite apex of said one rhombic to the adjacent apex of the other rhombic antenna, and adjustable impedance means connected in series with said last rhombic antenna at the apex adjacent said feeder system, said impedance means comprising a pair of parallel conductors with a conducting cross-piece thereacross and movable over the length of said parallel conductors.

8. An antenna system for transmitting or receiving a wide band of frequencies comprising a first conductor having a pair of separated arms extending in the same straight line, second and third conductors arranged parallel to and closely spaced from said first conductor, means for connecting said arms to said second and third conductors at points removed from said adjacent ends, whereby the impedance of said antenna system at said adjacent ends is increased over that of a single conductor dipole, and a two-conductor transmission line having a predetermined impedance directly connected to the adjacent ends of said pair of arms, the impedance of said antenna system at said adjacent ends being of the order of said transmission line, and an impedance connected in series with one of said second or third conductors intermediate its ends.

9. An antenna system for transmitting or receiving a wide band of frequencies comprising a first conductor having a pair of separated arms extending in the same straight line, second and third conductors arranged parallel to and closely spaced from said first conductor, means for connecting said arms to said second and third conductors at points removed from said adjacent ends, whereby the impedance of said antenna system at said adjacent ends is increased over that of a single conductor dipole, and a two-conductor transmission line having a predetermined impedance directly connected to the adjacent ends of said pair of arms, the impedance of said antenna system at said adjacent ends being of the order of said transmission line, and an impedance connected in series with each of said second and third conductors intermediate their respective ends.

10. A bipolar antenna element, comprising in combination, two wire elements directly connected together at their respective ends, said wire elements being parallel to each other and located close to each other compared to the shortest wavelength employed, one of said elements being adapted to be fed with current in its middle part, and an impedance connected in series with the middle part of the other of said wire elements, said impedance being calculated to let substantially only progressive waves moving in opposed directions to flow through said wire elements, said antenna element being characterized by its substantially constant radiation characteristics over a wide range of wavelengths.

11. An antenna system comprising two similar rhombic antennas connected to a translation device and having their corresponding elements positioned immediately adjacent one another, the remote terminals of one rhombic antenna being respectively directly connected to the corresponding remote terminals of the other rhombic antenna.

12. A unidirective antenna system comprising two rhombic antennas connected to a translation device and having their corresponding elements positioned immediately adjacent one another, the remote terminals of one rhombic antenna being respectively connected to the corresponding remote terminals of the other rhombic antenna, the near terminals of one rhombic antenna being adjustably connected together.

13. An antenna system comprising a conductor having a pair of separated arms, another conductor arranged parallel to said first conductor and closely spaced therefrom, a transmission line directly connected to the adjacent ends of said pair of arms, and means for connecting said arms to said other conductor at points removed from said adjacent ends, said other conductor having a lumped impedance located substantially in the center thereof connected electrically in series relation thereto, said lumped impedance comprising a pair of wires having a short circuiting strap thereacross.

14. An antenna system comprising a conductor having a pair of separated arms, another conductor arranged parallel to said first conductor and closely spaced therefrom, a transmission line directly connected to the adjacent ends of said pair of arms, and means for connecting said arms to said other conductor at points removed from said adjacent ends, said other conductor having a lumped impedance located substantially in the center thereof connected electrically in series relation thereto, said lumped impedance comprising a pair of wires coupled to said transmission line and having a short circuiting slider across said wires.

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