

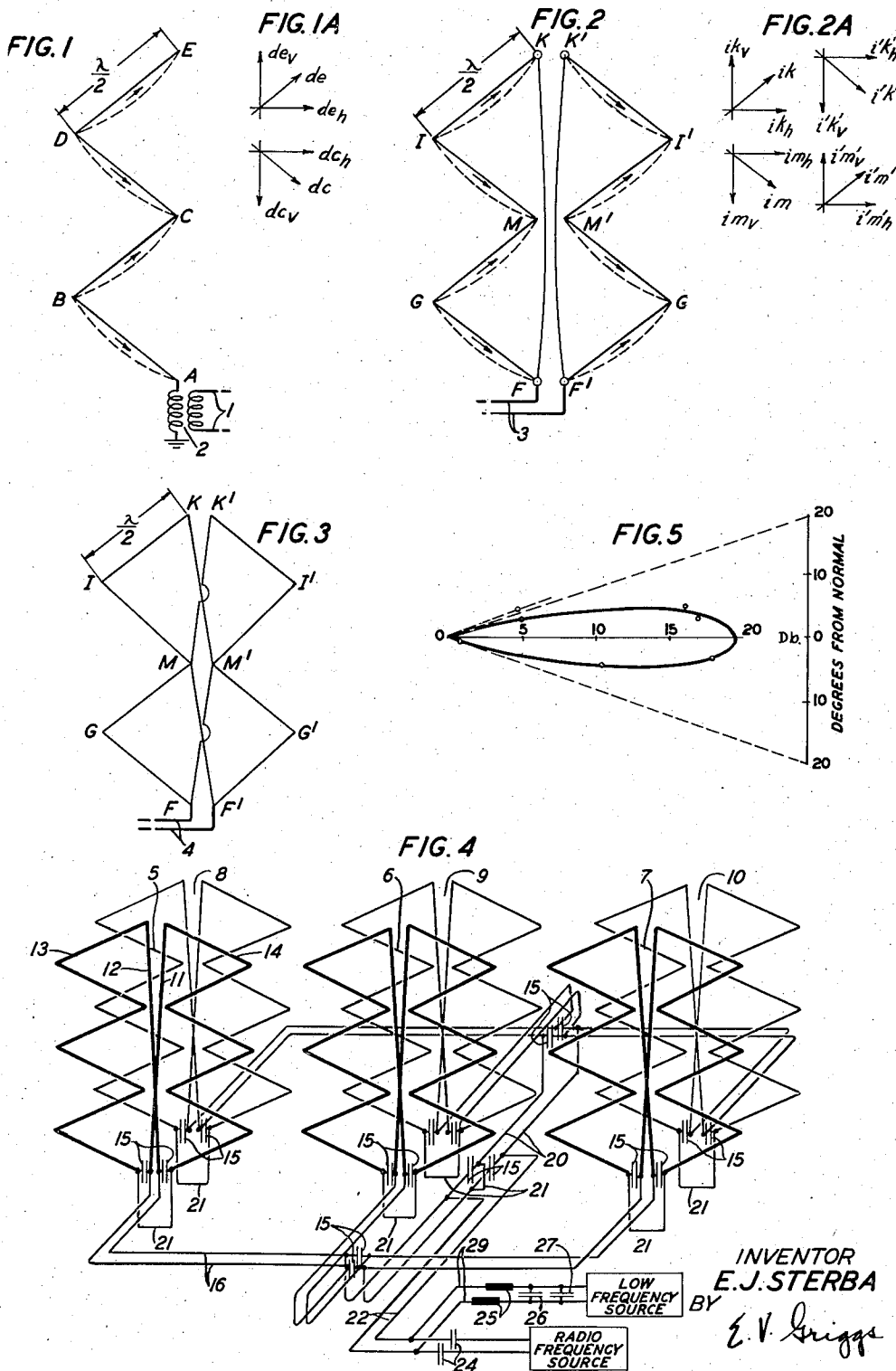
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ANTENNA SYSTEM

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ANTENNA SYSTEM

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This invention relates to antenna systems and more particularly to a directive antenna system.

An object of this invention is to obtain essentially horizontally polarized radiations from an antenna array.

Another object of this invention is to provide a closed circuit for removing sleet on all elements of an antenna array.

A more particular object of this invention is to increase the efficiency in the radio transmission and reception of horizontally polarized waves in a horizontal direction.

Since Heinrich Hertz in 1887 and 1888 constructed the first directive antenna, radio communication in all its phases has been markedly improved. In radio communication between two fixed stations, one most important factor from the economic standpoint is the utilization of power of a transmission station to the best advantage. Keeping in stride with the constant march of improvements in other branches of the radio communication art, directive antenna systems have been developed which, in addition to being more effective than the parabolic antenna of Hertz, are far more economical of construction. In some of these systems an inclined or bent wire radiates a component of desired polarization and an undesired component with a polarization normal to that of the desired component. To achieve conservation of power and to eliminate further fading and distortion, the substantial elimination of radiation of the undesired polarization is essential.

In accordance with this invention, an antenna system emits horizontally polarized wave components. The antenna system comprises a pair of zigzag radiating elements vertically arranged. Each element is reversely bent at approximately each half wave-length and is oppositely bent from the other element. The corresponding apices of the angles of zigzag elements are in the same horizontal plane. Non-radiating means supplies radio frequency power to the elements. The horizontally polarized components of the waves radiated from the elements are in phase, while the vertical components of the waves are substantially eliminated in all directions. A directly excited rear curtain having the same configuration as the system is also preferably employed in point-to-point radio transmission and reception.

A more comprehensive understanding of this invention is obtained by reference to the accompanying drawing in which:

Fig. 1 shows diagrammatically a zigzag antenna well known in the art;

Fig. 1A is a diagram of the polarized wave components emitted by part of the antenna of the type shown in Fig. 1;

Fig. 2 is a simple antenna constructed in accordance with this invention;

Fig. 2A shows diagrammatically the polarized wave component radiated by part of the system shown in Fig. 2;

Fig. 3 is a modification of the antenna system shown in Fig. 2;

Fig. 4 shows a broadside unidirectional antenna system and transmission system for interconnecting the panels comprising the system; and

Fig. 5 is a polar diagram in a horizontal plane of the directional characteristics of the system shown in Fig. 4.

In Fig. 1 a zigzag type of antenna is represented by the solid lines ABCDE. The antenna ABCDE is reversely bent at points B and C and D. Each of the sections AB, BC, CD and DE is of approximately one-half wave-length. Radio frequency current is supplied to the antenna ABCDE through a transformer 2 from a line 1. The dotted curve ABCDE and the arrows indicate the relative current amplitude and direction of the standing waves along the antenna. At any instant adjacent sections of the antenna such as AB and BC are energized by current flowing in opposite directions. Due to the mutual reactance of the conductors in the several sections, the wire length along the section is noticeably different than one-half wave-length depending upon the manner in which the wire is bent. The exact length which approximates one-half wave-length is determined empirically by methods well known in the art. One method of ascertaining the exact length is described in a paper entitled "Theoretical and practical aspects of directional transmitting systems" by E. J. Sterba published in the Proceedings of the Institute of Radio Engineers, July 1931, vol. 19, No. 7, pp. 1184 to 1215.

In Fig. 1A, the polarized wave components of the sections CD and DE are indicated by arrows. The arrows d_e and d_c indicate the relative current directions of the sections DE and DC, respectively. These currents may be resolved into vertical components d_{ev} and d_{cv} and into horizontal components d_{eh} and d_{ch} . Since the vertical current components are in opposite directions, the radiations due to the components substantially neutralize each other normal to the paper upon which the drawing appears, whereas

the radiations from each of the elements due to the horizontal components substantially aid each other in a horizontal direction. Accordingly, the components of the field radiated by DE and DC in a horizontal direction assist each other and result in a more concentrated emanation of signal energy. Although the undesirable vertical wave components are neutralized at a point in the plane normal to the paper, the vertical polarized wave components are not neutralized in all directions. For example, the vertical polarized components do not cancel in the direction ACE. The radiations from DC incur a phase lag in traveling the mean distance between DC and that of DE. As a result, the greatest efficiency for horizontally polarized transmission by the substantial reduction of the vertical polarized wave component is not obtained by the the system shown in Fig. 1.

Fig. 2 shows a directive antenna system for the emission of horizontally polarized wave components with the substantial reduction of the vertical wave components in all directions. The antenna comprises two elements represented in the drawing by the solid line FGMIK and F'G'M'I'K'. Each of the elements FGMIK and F'G'M'I'K' is reversely bent at the points G, M, I and G', M', I', respectively. The sections FG, GM, MI, IK, F'G', G'M', M'I', and I'K' are approximately one-half wave-length. Due to the mutual reactance of the several sections, the wire length along each section is not exactly one-half wave-length but approximates that length. The exact length of each element is determined empirically by methods well-known in the art. The points FF' are in a horizontal plane parallel to the ground. The corresponding apices of the angles of the two zigzag elements and including the pairs of points GG', MM', II' and KK' are each in horizontal planes parallel to the ground and parallel to that containing the points FF'. Energy is supplied to the two elements FGMIK and F'G'M'I'K' by means of a line 3 and non-radiating elements FK and F'K'. In order to secure proper phasing in the antenna sections or half wave elements, the lines FK and F'K' are each made equal in length to an even multiple of a half wave length since, as illustrated on the drawing, the zigzag antennas FGMIK and F'G'M'I'K' are each an even multiple of a half wave-length long and the extremities of each antenna, F and K of antenna FGMIK and F' and K' of antenna F'G'M'I'K', are connected to the same terminal of the radio frequency source. The relative amplitudes and directions of the currents supplied by the line 3 to the antenna elements are indicated by the dotted curves and arrows shown in Fig. 2. At any instant adjacent sections of each of the elements such as MI and IK or M'I' and I'K' are energized by current flowing in opposite directions.

The relative directions of the currents along each of the sections MI, IK, M'I', and I'K' are indicated in Fig. 2A. An arrow ik indicates the direction of the current energizing the section IK of the antenna shown in Fig. 2. Likewise arrows im , $i'k'$ and $i'm'$ represent the direction of the energizing current in sections IM, I'K', and I'M', respectively. These currents may be resolved into vertical and horizontal components. The horizontal current component in section IK is indicated by ik_h , while the vertical polarized current component is represented by the arrow labeled ik_v . Likewise, the horizontal current components in the sections IM, I'K', and I'M' are indicated by the arrows labeled im_h , $i'k'_h$ and $i'm'_h$, respec-

tively. The vertical current components in sections IM, I'K', and I'M' are indicated by arrows labeled im_v , $i'k'_v$ and $i'm'_v$, respectively. An examination of the representation of the vertical current components in the sections IK and IM reveals that, like the systems shown in Fig. 1, the vertical current component in these sections produce radiations which cancel in a plane normal to the drawing. For the reasons stated in the description of the antenna system shown in Fig. 1 the radiation due to the vertical current components in the section IK and IM, taken alone, do not cancel in the direction FMK. In a like manner, the radiation due to the vertical current components in the sections I'K' and I'M', if considered alone, do not cancel in the direction F'M'K'. It is observed, however, that the radiation due to the vertical current components in the section IK and that in the section I'K' are directed in opposite directions. Likewise, the radiation due to the vertical polarized components in sections IM and I'M' are in opposite directions. The vertically polarized component radiated by the sections IK and IM, together with those radiated by sections I'K' and I'M', not only cancel in a horizontal plane to that of the drawing, but in addition substantially cancel in the direction FMK and F'M'K'. Accordingly, when a zigzag element such as that shown in Fig. 1 and an oppositely bent element are employed to form the system shown in Fig. 2, there is a substantial reduction of the components of the undesired polarizations over and above that produced by the system shown in Fig. 1. On the other hand, the radiations from the horizontal current components of the section IK, IM, I'K' and I'M' are in the same direction, are additive in effect and result in a radiated horizontally polarized signal of greater intensity. The principle of radiation of the sections FG and GM and F'G' and G'M' is similar to that of IK, IM, I'K', and I'M'. Since the principle of operation of the radiating member comprising the sections FG, GM, F'G' and G'M' is the same as in the case of the radiating member comprising the sections IK, IM, I'K' and I'M', the combination of these sections operates to effect not only a more intense signal of the desired polarization, but also to further reduce signals of undesired polarization. Similarly, an additional advantage is obtained by employing a plurality of the elements shown in Fig. 2 arranged in a common panel. For example, a panel may comprise two or more of the antenna systems shown in Fig. 2 placed in the same vertical plane and supplied by a common radio frequency source.

Fig. 3 shows a modification of the system shown in Fig. 2. Two zigzag elements FGMIK and F'G'M'I'K' are supplied with radiating energy from a line 4. The elements FGMIK and F'G'M'I'K' are the same as those shown in Fig. 2 and the antenna system shown in Fig. 3 operates in a manner similar to that shown in Fig. 2 to substantially eliminate the vertical polarized wave component in all directions. Instead of connecting the non-radiating elements between points F and K and F' and K', the non-radiating elements are connected between F and M', M' and K, F' and M and M and K'. The phasing of the antenna sections is as depicted by Figs. 1A and 2. In order to secure the proper phasing, conductors FM'K and F'MK' of the transmission line, the impedance of which is inherently low as compared to that of each radiating section, are each made an even multiple of a half wave-length long for reasons pointed out in connection with the de-

scription of Fig. 2. Each of the lines FM'K and F'MK' must also have, in order to insure the proper phasing, a length equal to twice an odd multiple of a half wave-length inasmuch as in the case of each conductor the mid-point is connected to one of the zigzag antennas whereas the extremities are connected to the other zigzag antenna, and these antennas are associated with different terminals of the radio frequency source.

Considered from another standpoint, the energies arriving at M, for example, over the two paths FGM and F'M for utilization by conductor MI agree in phase. Since the points or extremities F and F' are oppositely phased and since the path FGM is a wave-length long, the path F'M must be made equivalent to an odd multiple of a half wave-length in order to secure the desired phase relation and current distributions illustrated by Figs. 1A and 2. Consequently, conductor sections FM', F'M, MK' and M'K are each an odd multiple of a half wave-length long. This type of construction of the antenna system is also advantageous in that a series connection of all elements for sleet melting currents may more readily be effected.

In Fig. 4, a perspective view of a complete unidirectional radiating system embodying this invention is shown. The system comprises three panels 5, 6, and 7 located in the same vertical plane. Each panel is similar to the antenna shown in Fig. 2, except that twelve instead of eight radiating sections are employed. This construction necessitates a reversal in the line connection in order to excite all radiating sections with currents in the proper amplitude and phase. For example, the panel 5 comprises two radiating elements 13 and 14. Radio frequency current is supplied to the radiating elements 13 and 14 from a line 16 through two non-radiating transposed or reversed elements 11 and 12. The non-radiating element 11 connects the lower terminal of the radiating element 13 with the top terminal of the radiating element 14, while the non-radiating element 12 connects the lower terminal of the radiating element 14 with the top terminal of the radiating element 13. The transposed conductors 11 and 12 are each an odd multiple of a half wave-length long.

Three other panels 8, 9, and 10 having the same configuration as panels 5, 6, and 7 and having non-radiating elements the same as those of panels 5, 6, and 7, lie in a vertical plane parallel to that containing panels 5, 6, and 7, and are symmetrically located an odd number of quarter wave-lengths to the rear of panels 5, 6, and 7, respectively. Both the front curtain of the system comprising panels 5, 6, and 7 and the rear curtain comprising panels 8, 9, and 10 are directly excited instead of permitting the rear curtain to obtain energy parasitically. The direct excitation of both curtains not only reduces the time required for tuning operations, but also greatly increases the accuracy of the adjustment for the null field to the rear of the system. A very deep null to the rear of the antenna by directly exciting both curtains in the proper phase relation is frequently obtained. The transmission line for supplying energy to the antenna system consists of a tie line 20 connected to the line 16 between the center panels 6 and 9 of the front and rear curtain. Energy is supplied to the tie line by means of a feed line 22 and is supplied from the tie line to the panels 5, 6, 7, 8, 9 and 10 by the line 16. The line 22 is connected to a radio frequency source through two condensers 24. The radio fre-

quency source is represented in the drawing by a labeled block diagram. A source of low frequency current indicated by the labeled block diagram is also connected to the line 22 by a line 29 through a quarter wave length line 25. Condensers 26 and 27 are connected across the line 29, the condenser 27 being at a quarter wave-length distance from the source of low frequency current and the condenser 26. The quarter wave-length line 25 together with the condensers 26 and 27 form an anti-resonant current at the frequency of the energy supplied by the radio frequency source. The condensers 24 are low frequency blocking condensers which prevent energy from the low frequency source from entering the high frequency source. In a manner described in U. S. 2,008,266, granted to E. J. Sterba on July 16, 1935, the antenna system is supplied with the low frequency current for sleet melting and the high frequency current for radio transmission.

Experiments have demonstrated that the tie line 20 should preferably be an odd number of quarter wave-lengths long. The tie line 20 is connected straight across without crossing if it is $\frac{3}{4}$, $1\frac{1}{4}$, etc., wave-lengths long and is crossed (180 degrees phase reversal) if it is $1\frac{1}{4}$, $2\frac{1}{4}$, etc., wave-lengths long. The feed line 22 is tapped across the tie line 20 at a point approximately $\frac{1}{4}$, $1\frac{1}{4}$, etc., wave-lengths from the rear curtain. The best position is critical to within a few inches and depends to a certain extent upon the accuracy of the tie line length. It has been found that if the tie line length is either increased or decreased as much as an eighth wave-length from the optimum odd quarter value, the required position of the feed tap is found to move on the tie line by approximately an equal distance.

From the standpoint of the suppression of signals of undesired polarization and the reinforcement of signals of the desired polarization, the principle of operation of the system shown in Fig. 4 is similar to that shown in Fig. 2. However, by properly selecting the phase and amplitude of the radiating currents in the two curtains, a unidirectional radiating characteristic is obtained.

The standing wave loops on the half wave-length elements of each zigzag antenna in the systems of Figs. 2, 3 and 4 are considerably larger in amplitude and produce greater radiated components than those established on the half wave-length elements of the prior art system illustrated by Fig. 1, since the extremities of each zigzag element and also the mid-points of the elements in the system illustrated by Fig. 3 are directly connected to the transmission line whereby the traveling waves from the source follow diverse or relatively short paths, undergo minimum attenuation and initiate strong standing waves at the apex or mid-point of the radiating structure.

The system of Fig. 4 is also arranged for simultaneous energization with sleet melting and radio frequency current. Referring to Fig. 4, blocking condensers 14 which are capable of passing high or radio frequency currents but which effectively block the low frequency or direct currents employed for sleet melting, are associated with the array of each panel, the tie line 20 and the transmission line 16. A wave impedance 21 is also connected to the two elements of each panel and to the line 11. Each wave impedance 21 is of the conductive type and comprises two parallel conductors, preferably consisting of copper tubing, an odd multiple of quarter wave-length long and short-circuited at the far end by means of a

solid metallic bar or other conductor. Each of these impedances offers substantially infinite impedance to waves of a particular frequency. In a manner similar to the system described in the above stated patent of applicant, the condensers and impedances are arranged in the system so that the panels are connected in series for sleet melting current, while the panels are in parallel for the radio frequency wave propagation.

Fig. 5 shows the ratio of the horizontally polarized components in a horizontal plane along the earth radiated by the system shown in Fig. 4 and that radiated by a single half wave-length antenna which is placed at the mean height of the directional antenna. The solid curve is the theoretically calculated result, while the points are the actual experimental observations. The data from which the points were plotted include only the angular range extending between the two nulls on two sides of the principal lobe. Examination of Fig. 5 reveals that for equal power supplied to the simple horizontal antenna and to the array of Fig. 4 there are 19 decibels improvement in a horizontal direction.

While preferred embodiments in this invention have been illustrated and described, various modifications therein may be made without departing from the scope of the appended claims.

What is claimed is:

1. An antenna system comprising a plurality of pairs of zigzag, vertically arranged radiating elements comprising a plurality of sections, the length of a section of each element being approximately one-half wave-length, the corresponding angles of each of said element of said pair being oppositely bent from the other element of the pair and the apices of the corresponding angle of the elements of each pair being in the same horizontal plane, a second plurality of pairs of radiating elements substantially identical with said first plurality of vertically arranged zigzag elements and means for exciting directly said plurality of elements and said second plurality of elements comprising a connection between a source of energy and each extremity of each zigzag element.

2. An antenna system comprising a front curtain comprising three panels arranged vertically, each panel comprising a radiating element reversely bent at approximately each half wave-length and an identical element but oppositely reversely bent, a rear curtain substantially identical with said front curtain, a source of radio frequency current and non-radiating means for supplying current from said source directly to each extremity of each element included in said front and rear curtains.

3. A radiating system comprising a first V-shaped vertically arranged radiating member, approximately one-half wave-length on a side, a second V-shaped radiating member, approximately one-half wave-length on a side arranged in the same vertical plane as said first member, the opening of said first member facing the opening of said second member, a source of radio frequency current and means for supplying from both terminals of said source in-phase currents to the extremities of each member, the currents supplied to the terminals of one member being in opposite phase with respect to the currents supplied to the other member, whereby the member sides extending in parallel directions are energized in phase and only a horizontally polarized field is effectively radiated.

4. A radiating system comprising a first stack of V-shaped radiating members, approximately

one-half wave-length on a side, serially connected to each other and arranged in the same vertical plane, a second set of V-shaped stacks, approximately one-half a wave-length on a side, serially connected to each other, arranged in the same vertical plane as said first stack, said V-shaped members of said second stack facing the corresponding wave-length long, each of the sections of each of radio frequency waves and a transmission line for supplying from different terminals of said source in-phase radio frequency waves to the extremities of each stack and oppositely phased waves to said first and said second stacks whereby substantially strong standing waves are established on each half wave-length element and only horizontally polarized wave components are radiated.

5. A radiating system comprising three radiating panels, arranged in the same vertical plane, each of said panels comprising two zigzag elements having sections approximately one-half a wave-length long, each of the sections of each of said elements being symmetrical with but oppositely bent from adjacent sections of said element, a source of waves and non-radiating means for supplying waves from said source to a plurality of points in each of said panels.

6. In a radio system, an antenna comprising a plurality of serially connected half wave-length radiating sections arranged to form a zigzag element, a source of radio frequency energy, a counterpoise and means for supplying in-phase energy to the extremities of said antenna and energy oppositely phased to said first-mentioned energy to said counterpoise.

7. A system in accordance with claim 6, said counterpoise comprising a plurality of half wave-length radiating sections arranged to form a zigzag element, said means comprising a pair of connections extending from the opposite terminals of said source to said extremities and a similar pair of connections extending to the extremities of said counterpoise, and a low frequency source connected in series with said antenna and counterpoise.

8. In a radio system, a pair of antennas, the corresponding terminals of which are more closely positioned than the terminals of either antenna, and means for simultaneously energizing said antennas with radio frequency current and sleet-melting current, said means comprising a sleet-melting current source, a radio frequency source, and a line for connecting said sources to each antenna, a first terminal of the first antenna being connected through a low frequency impedance to one line conductor and the corresponding first terminal of the second antenna being connected through a similar impedance to the other line conductor, the second terminal of the first antenna being connected through a path of substantially zero impedance to the second-mentioned line conductor and the corresponding second terminal of the second antenna being connected through a similar path to the first-mentioned conductor, and a path of substantially zero impedance for the sleet melting current connecting the corresponding first terminals of said antennas.

9. In a radio system, an antenna, a counterpoise, a translation device connected to one set of corresponding points on said antenna and counterpoise, a transmission line connecting said points to a second set of corresponding points on said antenna and counterpoise electrically separated from the first set by at least two wave-lengths, the conductors of said line being positioned relatively close together, and said line being shorter

electrically than each of the antenna and counterpoise portions included between said two sets of points and having a relatively low impedance, whereby substantially no radiation occurs from said line and a maximum amount of energy is delivered to said second set of points.

10. In combination, a zigzag antenna element having a pair of terminals and a length equal to a plurality of wave-lengths, a zigzag counterpoise element having the same length and a pair of terminals, a transmitter connected between one set of corresponding antenna and counterpoise ter-

minals, a line connecting said set of terminals and the remaining set of corresponding terminals, the conductors of said line being positioned relatively close together and each having an electrical length less than that of the antenna or the counterpoise and equal to a multiple of a half wavelength, and said line having a relatively low impedance, whereby substantially no radiation occurs from said line and a maximum amount of energy is delivered to said remaining set of terminals.

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