Aug. 5, 1947.

H. G. BUSIGNIES

2,424,968

DIRECTIVE ANTENNA SYSTEM

Filed June 2, 1942

3 Sheets-Sheet 1

Fig. 1.

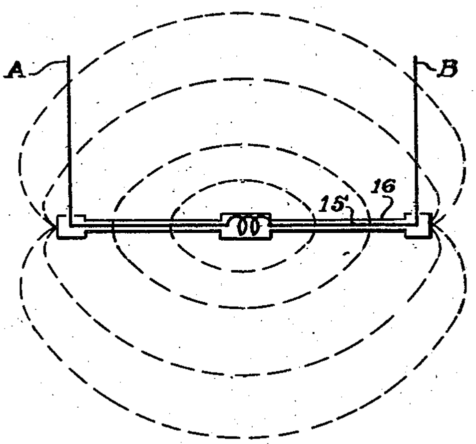

Fig. 2.

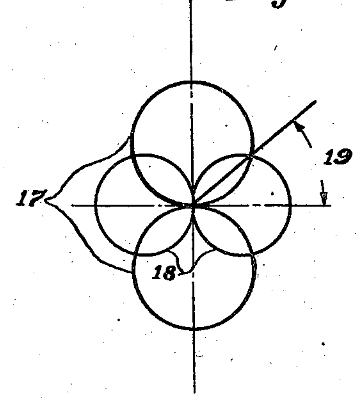

Fig. 3.

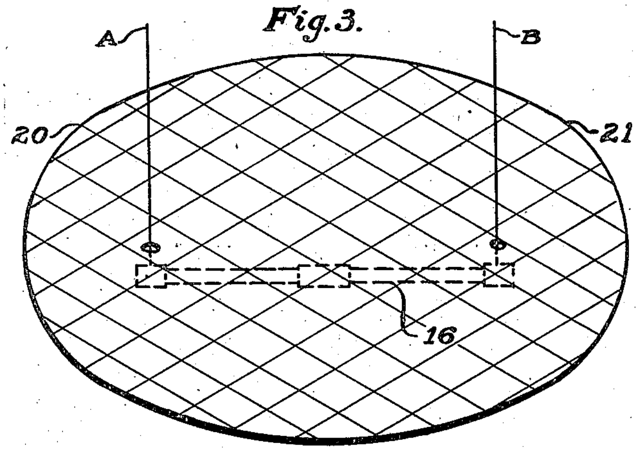

Fig. 6.

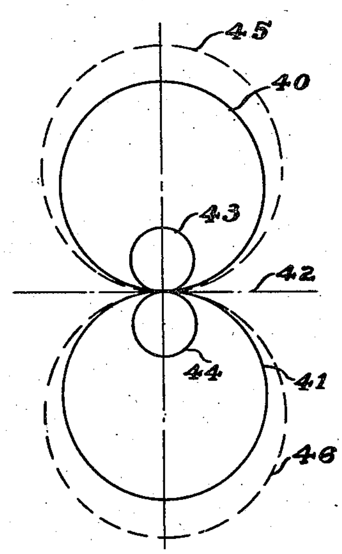

Fig. 4.

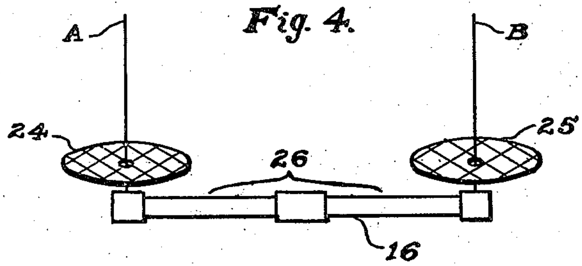

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Fig. 5.

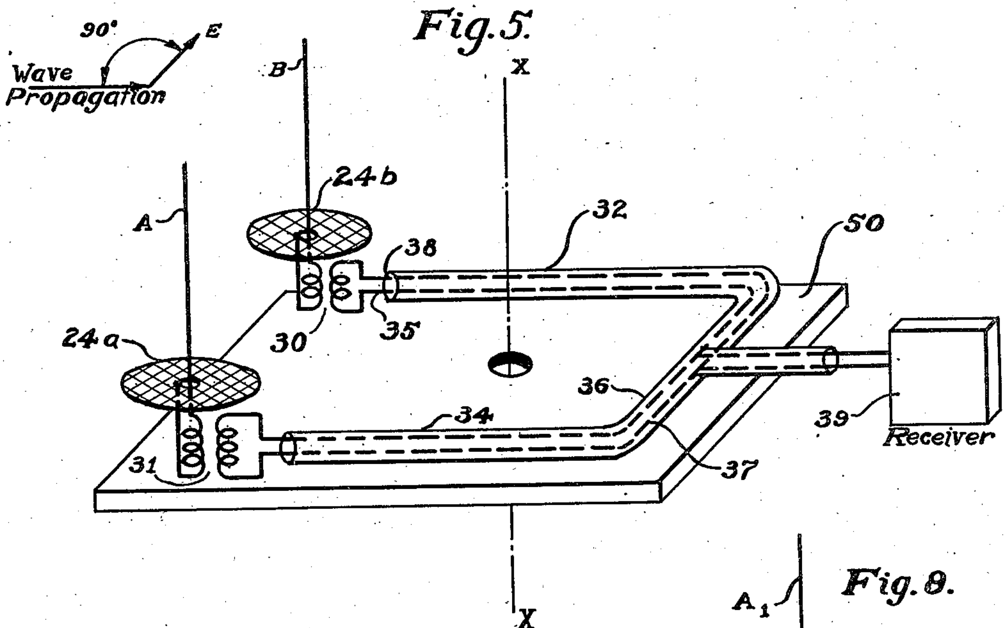

Fig. 8.

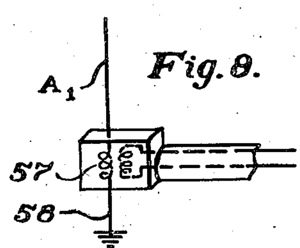

Fig. 7.

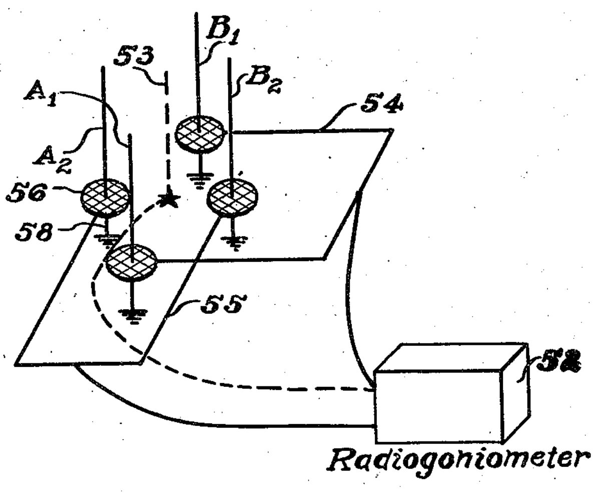

Fig. 9.

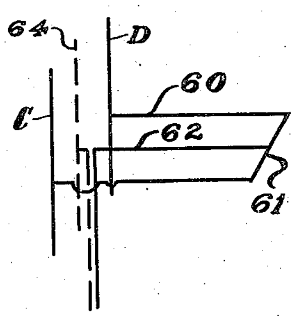

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Fig. 10.

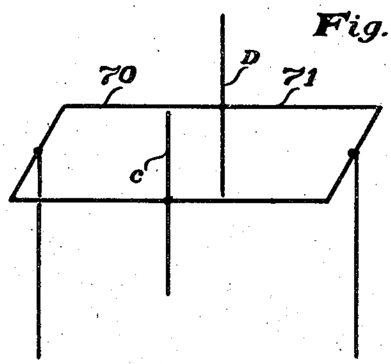


Fig. 11

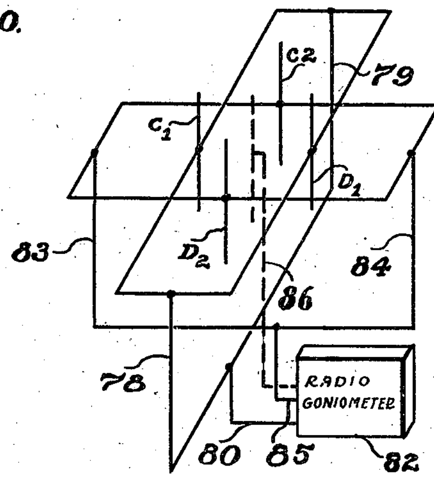


Fig. 12.

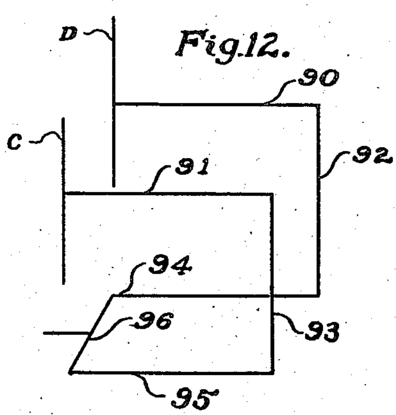


Fig. 14.

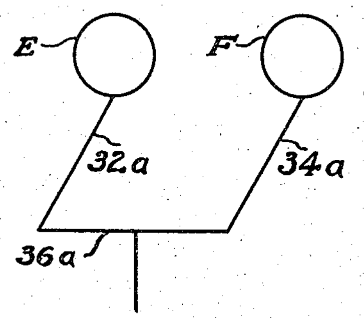
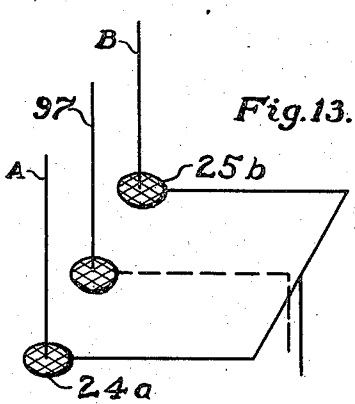


Fig. 13.



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UNITED STATES PATENT OFFICE

2,425,968

DIRECTIVE ANTENNA SYSTEM

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Application June 2, 1942, Serial No. 445,468

13 Claims. (Cl. 250—11)

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This invention relates to direction finding apparatus and more particularly to improvements in directional antennae therefor.

One of the objects of the invention is to provide a directional antenna and associated transmission line so that the parasitic diagram of reception in horizontal polarization is so oriented with respect to the useful directive diagram of reception in vertical polarization that a null line of the former coincides with the null line of the latter.

Another object of the invention is to provide an improved antenna of the vertically disposed, spaced apart and electrically coupled together aerial types in which the portion of the transmission line spanning the space between the corresponding aerials is so disposed with respect to the aerials that for an electrical field in which the reception by the aerials is null, there is substantially no induction in the aerials due to E. M. F.'s produced in spanning the portion of the transmission line.

Still another object of the invention is to provide a plurality of monopole, dipole, or loop aerials, connected together by transmission lines in such an arrangement as to greatly minimize the parasitic horizontal polarization reception effect by the lines for the null vertical polarization reception by the aerials.

A further object of the invention is to provide a portable directional antenna of the spaced apart aerial types in which the interconnecting transmission lines may be laid out on the ground or on a platform for the taking of quick and accurate bearings.

The above and other objects of the invention will become more apparent upon consideration of the following detailed description when read in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatical representation of a simple form of U-type Adcock antenna having a shielded horizontal transmission line and illustrating the reflection of the E. M. F.'s produced in the shield of the transmission line;

Fig. 2 is a diagram illustrating the polarization errors of an antenna such as illustrated in Fig. 1;

Fig. 3 is a diagrammatical illustration of a U-type antenna provided with a large ground mat;

Fig. 4 is a diagrammatical illustration of a U-type antenna in which each of the poles is provided with an individual ground mat in accordance with one of the features of this invention;

Fig. 5 is a diagrammatical illustration of a rotatable U-type antenna structure in accordance with the invention;

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Fig. 6 is a polar diagram illustrating the operating results of an antennae constructed such as shown in Fig. 5;

Fig. 7 shows schematically a plural U-type antenna connected to a radio-goniometer;

Fig. 8 is a fragmentary illustration of the base portion of one of the aerials shown in Fig. 7 together with a diagrammatical showing of the transmission line coupling therefor; and

Figs. 9 through 14 are schematical illustrations of other antenna arrangements in accordance with this invention.

Referring to the prior art Adcock U-type antenna illustrated in Fig. 1 of the drawings, it will be recalled that Adcock in developing this type of antenna was endeavoring to overcome the horizontal polarization reception effects produced in the horizontal portions of the loop type of antenna so as to produce an antenna system which would only respond to vertically polarized energy. In the form illustrated in Fig. 1, the active aerial parts comprise spaced vertical monopoles A and B and a horizontal connecting line 15. Considerable effort was made heretofore to dispose the horizontal line so that either no E. M. F. could be induced in it, or alternatively, if it were, that it should be balanced out so that the only energy delivered to the receiver would be energy from vertically polarized signals received in the vertical monopoles. In attempting to effect this result, Adcock proposed to place the horizontal line below the surface of a perfectly conducting earth. But since it is difficult to find an earth having perfect conduction, Adcock proposed shielding the horizontal line in the manner illustrated in Fig. 1. The addition of tubular shield 16 does prevent the unwanted horizontally polarized waves from acting upon line 15, but unfortunately makes it possible for these horizontally polarized waves to act directly upon monopoles A and B, for the horizontally polarized waves directly act upon shield tube 16 to produce differences in potential and charge at the ends of the tube; and these charges establish electric forces as indicated by the dotted lines in Fig. 1. These lines of force have vertical components in the neighborhood of the vertical aerials A and B and thereby induce voltages therein. Thus monopoles A and B indirectly respond to the undesired horizontally polarized waves. This is diagrammatically illustrated in Fig. 2. The circles 17 represent the vertical polarization reception diagrams and the circles 18 represent the horizontal polarization reception diagrams whose maxima are rotated 90° with respect to those of diagram 17. The direction of smallest combined reception of all types of energy will therefore differ by an angle 19 from the direction of null reception for vertically polarized energy (this latter null being the true direction of propagation). It is one of the objects of my invention to greatly reduce or substantially eliminate the angle 19.

In addition to the above-mentioned forms, it was proposed to have the tube buried several feet under the surface of the ground and to connect it to earth plates with extended earth wires to insure good earth conduction therefor. Thus buried, the antenna produces reasonably good results but for portable purposes, is of course impractical.

It is known that if the horizontal transmission line were covered by a greatly extended ground mat either of solid metal or made of screen material and having dimensions which may be regarded as corresponding to infinity, that the result of the buried transmission line would be achieved. With this in mind, tests were made upon a U-type Adcock antenna with a ground mat reduced in size substantially as illustrated in Fig. 3. The results, however, were entirely unsatisfactory. The poor results of the large ground mat shown in Fig. 3 were apparently due to the fact that the mat for each pole was unsymmetrical. By this I mean to say that the edge portion 20 was much closer to the pole A than the opposite edge portion 21. Thus, when a positive electrostatic charge is established at 20 and a negative electrostatic charge is established at 21, the resulting unsymmetrical arrangement of the lines of force established thereby produce a flow of current in the pole A. Likewise, the charge produces a flow of current in the pole B opposite in direction to the flow in the pole A. This induction of the horizontal polarized reception effect of the ground mat introduces error of considerable proportions in the vertical polarization reception of signals by the aerials A and B.

Contrary to the teachings of the art, I have found that the errors of reception which occurred in the use of a large ground mat such as illustrated in Fig. 3 were considerably reduced by decreasing the dimensions of the ground mats and separating the mats so as to produce in effect individual symmetrical mats 24 and 25 for the monopoles. This improved form of antenna is illustrated in Fig. 4. While the individual ground mat arrangement was an improvement over the larger mat illustrated in Fig. 3, very substantial errors were nevertheless found to exist and these I believe were due to an induction of the horizontal polarization reception by the exposed portion 26 of the tubing 16. By considerable experimenting and effort, I finally discovered that it is possible to substantially eliminate the horizontal polarization reception effect or at least orient it 90° so that it is practically zero for the same direction of propagation for which the vertical polarization reception is zero. This is done by locating the portion of the transmission line which spans the space between the aerial poles a distance from the poles A and B. This relation greatly reduces or substantially eliminates induction effects in the aerials A and B of E. M. F.'s set up in the spanning portion of the transmission line. The spanning portion of the line is connected to the aerials by two parallelly arranged portions each coupled to one of the aerials and extending at right angles to the plane containing the two aerials. This orientation of the adjacent portions of the transmission line likewise orients by 90° the horizontal polarization reception effect of such adjacent portions so that the reception diagram is in the direction of the reception diagram of the vertical polarization. Thus for an electrical field in which the vertical polarization reception of the aerial poles A and B is null, the horizontal polarization reception effect is also null as indicated by the circles 40, 41 and 43, 44 in Fig. 6 hereinafter described.

An antenna in accordance with this discovery is illustrated in Fig. 5. The monopoles A and B are vertically supported and are provided with transformers 30 and 31 which may be of the type illustrated in my copending application Serial No. 384,670, filed March 22, 1941; and H. Busignies and A. Richardson, Serial No. 440,154, filed April 23, 1942. The transmission line which connects the monopoles A and B through the transformers 30 and 31 to receiver 39 comprises two conductors 35 transposed at 37 and shielded by a suitable insulating covering or cable 38. The line comprises two parallelly arranged portions 32 and 34 and a third portion 36 connected together with portions 32 and 34. The portions 32 and 34 are disposed at right angles to the plane of the monopoles with which they are coupled, and the third portion 36 is disposed at right angles to the portions 32 and 34 and at a distance from the poles A and B. With the horizontal portion 36 located a suitable distance from the poles A and B, I find that the parasitic induction to the poles A and B from the portion 36 may be substantially eliminated. A satisfactory distance for the spacing of the portion 36 from the aerials A and B for portable purposes is about one and one-half times the spacing between the aerials or more, though considerable advantage is observed even when this distance is as little as two-thirds the aerial spacing. It will be understood of course, that the spacing of the portion 36 with respect to the aerials A and B may be increased as much as desired, the reduction in the induction effect tapering off more and more gradually as the distance is increased.

The portions 32 and 34 being perpendicular to the plane of the aerials A and B (whereby these portions lie in the direction of wave propagation, when the system is oriented for zero reception of the desired vertically polarized electrical field) the parasitic diagram or horizontal polarization reception effect produced by induction of the E. M. F.'s in these portions may be said to be oriented in substantially the same direction as the useful directive diagrams of vertical polarization reception (Fig. 6). The useful diagram 40, 41 of reception of vertical polarized energy produces a null line 42. The parasitic diagram of reception of horizontal polarized energy being that developed from the parallelly arranged portions 32 and 34, is oriented 90° from the parasitic diagram of reception of the spanning portion 36 of Fig. 2 (which due to its distance from the poles A and B may now be disregarded) as indicated by diagram 43—44. The diagram 43—44 is additive to the diagram 40—41 and the null line thereof coincides with the null line 42. This additive effect results in larger diagram effects as indicated by the combined diagram 45—46. Thus, for downcoming and tilted waves, the null of the parasitic diagrams for a two aerial antenna (Fig. 5) which may be rotated to bring the parallelly arranged portions 32 and 34 parallel to the direction of wave propagation, coincides with the null of the useful directive diagrams and results in a greatly improved antenna system.

I have found that by using ground mats *24a* and *24b* for the monopole type of antennae illustrated in Fig. 5, the induction effect of the transmission cables 32 and 34 is reduced. This reduction is due no doubt, to the overlying relation of the mat to the end portions of the transmission cable closely adjacent the poles. This I find particularly helpful where four monopoles are used as indicated in Fig. 7. A platform 50 may be provided to rotatably support the poles A and B together with the transmission line 32, 34 and 36 about a vertical axis XX. Thus supported, the antenna may be shifted in accordance with reception to determine the direction of propagation of signals received.

When four monopoles A1, B1, A2 and B2 (Fig. 7) are used, the rotatable support may be replaced by a suitable radiogoniometer 52 to which the transmission lines 54 and 55 of the two pairs of monopoles may be connected. Each transmission line, though represented by a single line is a two-wire shielded line. Each aerial may be provided with a ground mat 56 together with a transformer 57 (Fig. 8) or the ground mat 56 omitted. The mat and one lead of the transformer winding may be connected to ground. When the transformer lead 58 is grounded, the mat may be dispensed with. By using a radiogoniometer with the system illustrated in Fig. 7, the transmission cable may be laid upon the ground in the desired relation and the direction of wave propagation determined by movement of the rotary coil of the radiogoniometer. The parallel portions of the transmission cable of each pair of aerials are disposed at right angles to the plane of such aerials, the planes of the two pairs of aerials being disposed at right angles. With this arrangement, the pattern of reception of horizontally polarized waves may be somewhat misaligned with respect to the main pattern since the parallel portions of 54 may influence monopoles A2 and B2 while the parallel portions of 55 may influence A1 and B1. But the horizontal polarization pattern even if not perfectly aligned with the main pattern is at any rate oriented more favorably than that of Fig. 2 being made up of two components oriented as in Figs. 2 and 6 respectively. A centrally disposed sensing aerial 53 may be provided and connected to the radiogoniometer in the usual way.

In Fig. 9 I have illustrated schematically a pair of elevated dipoles C and D arranged in accordance with my invention wherein the transmission cable 60 which is shown for simplicity of illustration as a single line may include transmission wires spaced inside a metallic shield tubing or covering and coupling transformers substantially as shown in Fig. 5, the coupling transformers being preferably of the form of vacuum tube amplifiers with impedance transforming characteristics in accordance with the disclosures of the aforesaid copending applications. As indicated in Fig. 9, the leads from the spanning portion 61 of the cable may be extended back to the plane of the dipoles C and D and brought down along the axis of rotation of the antenna together with the lead of the sensing dipole 64. A dipole antenna system as illustrated in Fig. 9 will be elevated on a suitable rotatable supporting structure.

The induction effect of the transmission cable portions 32 and 34 (Fig. 5) may be reduced or balanced by duplicating the transmission cable arrangement substantially as illustrated in Fig. 10. In Fig. 10, the aerials are shown to be dipoles C and D the same as illustrated in Fig. 9, but it will be understood that the balanced transmission lines may also be used with monopoles or spaced loop aerials. The balancing cable portions 70 and 71 may be connected together at the dipole coupling or the shield tubing thereof may be separated at the dipoles.

A fixed elevated four-dipole system is shown in Fig. 11 where each pair of dipoles C1, D1 and C2, D2 is provided with balanced transmission cables. The leads 78 and 79 from each set of balanced cables are brought down and connected together for connection by a line 80 to a suitable radiogoniometer 82. Likewise, the leads 83 and 84 of the other set of balanced cables are connected together and provided with a lead 85 for connection to the radiogoniometer. A sensing aerial 86 may also be provided for this system in the usual way.

In Fig. 12, a pair of dipoles C and D are shown connected by a transmission cable comprising laterally extending portions 90 and 91 extending at right angles to the plane of the dipoles, two vertically extending portions 92 and 93 and two horizontal portions 94 and 95 extending parallel to the portions 90 and 91 back to the plane of the dipoles. The ends of the portions 94 and 95 are connected together by a horizontal portion 96 at a distance from the dipoles C and D. Thus, the horizontal spanning portion 96 may be disposed in the plane of the aerials but at such a distance from the aerials as not to have any adverse induction effect thereon. The portion 96 may be, if desired, connected anywhere across the portions 92, 93 or 94, 95.

While I have shown dipoles in Figs. 9 to 12, it will be understood that the dipoles may be replaced by elevated monopoles A and B substantially as indicated in Fig. 13. A sensing aerial 97 may also be provided. Where monopoles are used, I prefer to use ground mats *24a* and *25b* but it will be understood that they may be eliminated, the result being a difference in the strength of the parasite horizontal polarization effect. Since the null line of this horizontal effect is more or less in line with the null of the useful directive diagram of the vertical polarization, the amplitude of the horizontal polarization, even when of relatively considerable strength, introduces much less error than in conventional systems.

A pair of spaced loop antennae E and F are shown in Fig. 14, connected by an offset transmission line in accordance with this invention. The horizontal portion *36a* of the transmission line which spans the space between the loops, being at a distance from the loops, does not produce any appreciable parasitic induction in the loops as heretofore experienced when the transmission line was disposed directly between the loops. The parallelly arranged portions *32a* and *34a* being disposed at right angles to the plane of the loops provide a horizontal polarization which is additive to the vertical polarization reception the same as explained in connection with the form shown in Fig. 5.

While the arrangements of the transmission lines of the antennae systems herein disclosed are particularly suitable for portable use, such as when time and trouble cannot be taken to bury the transmission lines, it will be understood that the transmission lines may be buried, if desired, especially if the systems are to be stationary.

If the lateral extending portions of the line as well as the spanning portion are buried, the effect will be to reduce the horizontal polarization diagrams 43, 44 of Fig. 6. The ground mats 24a and 24b (Fig. 5) produce this effect to a large extent since they shield the portions of the transmission lines adjacent the poles.

While I have shown several antennae systems together with a number of transmission line arrangements, I recongize that many additional antenna arrangements and transmission line variations may be made without departing from my invention. It will be understood, therefore, that the embodiments herein shown and described are to be regarded as illustrative of the invention only and not as restricting the appended claims.

What I claim is:

1. A directional antenna comprising a plurality of spaced apart vertically disposed aerials, a transmission line, a shielding covering therefor, said line coupling together electrically at least two of said aerials, and having the major part of the portion of the line spanning the space between the two aerials disposed at a distance equal to at least two-thirds of the spacing between said aerials from the plane of said two aerials such that the parasitic induction produced in said aerials by electrical forces in the covering of said portion is reduced to an inconsequential amount.

2. A directional antenna comprising a plurality of spaced apart vertically disposed aerials, a transmission line, a shielding covering therefor, said line coupling together electrically at least two of said aerials, the portion of the line spanning the space between the two aerials being disposed at a distance of at least two-thirds the spacing between said aerials from the plane of said two aerials such that the parasitic induction produced in said aerials by electrical forces in the covering of said portion is reduced to an inconsequential amount, and the covering of the portions of the line extending between said first mentioned portion and the aerials being extended away from the plane of said aerials to cause a null line of the diagrams of parasitic induction of horizontal polarization reception by the covering of said portions coincides substantially with the null line of the useful direction diagrams of vertical polarization reception.

3. A directional antenna comprising a plurality of spaced apart vertically disposed aerials, a transmission line coupling together electrically at least two of said aerials, two portions of said line being arranged parallel to each other and extending at right angles to the plane of said aerials, and a third portion of the line coupling together said two portions at a distance from said aerials equal to about one and one-half times the spacing between said aerials.

4. A directional antenna comprising two vertically disposed aerials spaced apart and coupled together electrically by a transmission line, and said line having two portions thereof extending at right angles to the plane of said aerials and another portion spaced a distance from said aerials equal to about one and one-half times the spacing between said aerials and disposed parallel to the plane of the aerials.

5. A directional antenna comprising two spaced apart vertically disposed aerials spaced apart and coupled together electrically by a transmission line, said line having two portions thereof extending at right angles to the plane of said aerials, and a third portion coupling together said two portions at a distance from said plane, said distance being greater than the spacing between the two aerials.

6. A directional antenna comprising two vertically disposed aerials spaced apart and coupled together electrically by a transmission line, said line having two portions thereof extending at right angles to the plane of said aerials, a third portion spaced a distance from said aerials greater than the spacing between said aerials and coupling together said two portions, and a rotatable support for said aerials and said transmission line.

7. A directional antenna comprising two vertically disposed aerials spaced apart and coupled together electrically by a pair of transformers, one connected to each aerial, and a transmission line a shielding covering therefor, said line having two portions thereof extending at right angles to the plane of said aerials, and a third portion spaced a distance greater than two-thirds the spacing between said aerials from said aerials and disposed parallel to the plane of the aerials, said distance being such that the parasitic induction produced in said aerials by electrical forces in the covering of said portion is reduced to an inconsequential amount.

8. A directional antenna comprising two vertically disposed monopoles spaced apart and coupled together electrically by a pair of transformers, one connected to each aerial, and a transmission line, the windings of the transformers connected to the monopoles having a lead connectable to ground and said line having two portions thereof extending at right angles to the plane of said aerials and a third portion connecting together said two portions at a distance from said aerials greater than the spacing between said aerials.

9. A directional antenna comprising two pairs of spaced apart vertically disposed aerials, a transmission line coupling together electrically the aerials of each pair, each line having two portions extending at right angles to the plane of the aerials to which they are connected and a third portion coupling together said two portions at a distance from said aerials greater than the spacing between said aerials, a radiogoniometer, and leads extending from the mid-portion of each of the third portions of each line for connection to said radiogoniometer.

10. A directional antenna comprising two pairs of spaced apart vertically disposed monopoles, a transmission line coupling together electrically the monopoles of each pair, each line having two portions extending at right angles to the plane of the poles to which they are connected and a third portion coupling together said two portions at a distance from said monopoles at least as great as two-thirds the spacing between said monopoles, and a symmetrical ground mat disposed at the base of each monopole and overlying a portion of the line connected to the monopole.

11. A directional antenna comprising a pair of elevated, vertically disposed, spaced apart dipoles, a transmission line electrically coupling together said dipoles, said line having two portions thereof extending at right angles to the plane of said dipoles, and a third portion spaced a distance from said dipoles greater than the spacing between said dipoles and coupling together said two portions.

12. A directional antenna comprising a plurality of spaced apart vertically disposed aerials, a transmission line, a shielding covering therefor,

said line coupling together electrically at least two of said aerials, and the portions of the line adjacent the aerials being in a plane at substantially right angles to the plane of the aerials, and said portions being extended away from the aerials at a distance equal at least to two-thirds the spacing between said aerials so that the parasitic induction produced in said aerials be electrical forces in the covering of said portions is an inconsequential amount.

13. A directional antenna comprising a plurality of spaced apart vertically disposed aerials, a transmission line coupling together electrically at least two of said aerials, the two portions of said line adjacent said aerials being arranged parallel to each other and extending at right angles to the plane of said aerials, and a third portion of the line coupling together said two portions at a distance from said aerials greater than the spacing between said aerials, and means shielding said third portion of the line.

HENRI G. BUSIGNIES.

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