

April 6, 1937.

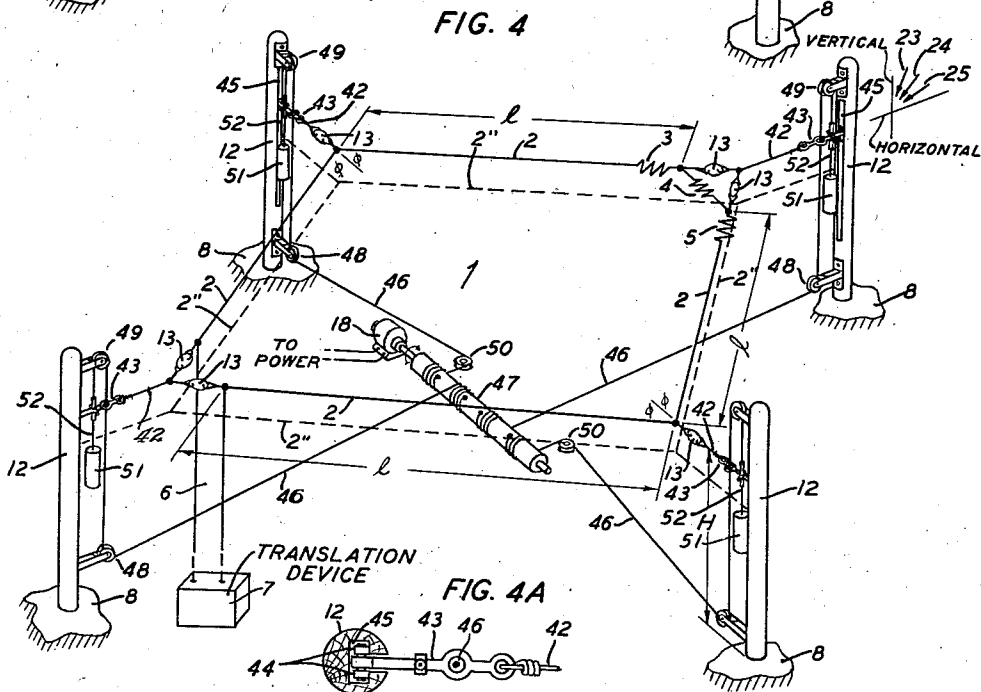
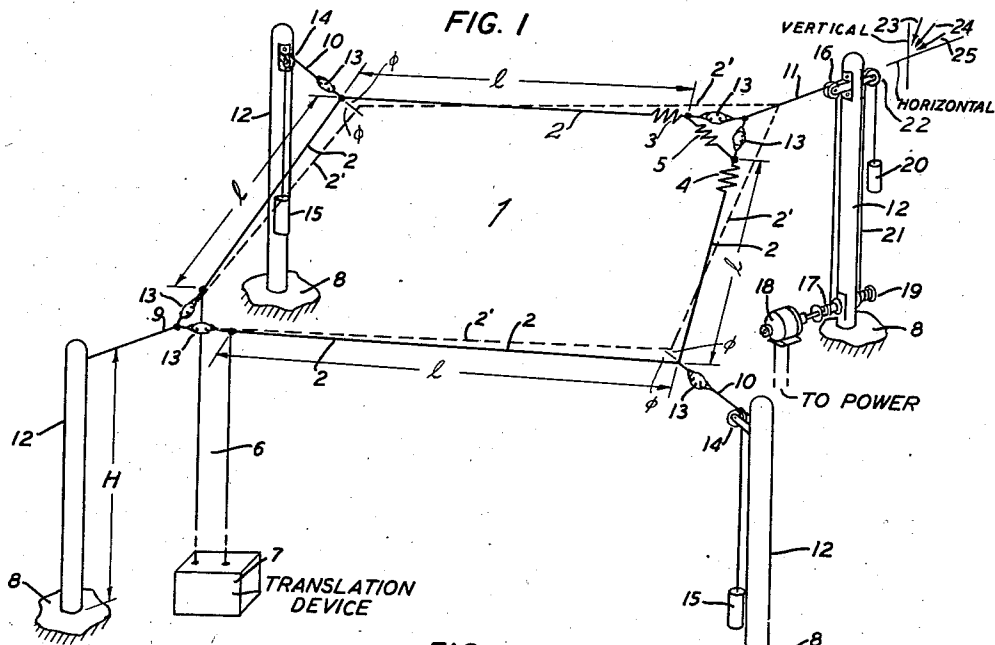
E. BRUCE

2,076,222

DIRECTIVE RADIO SYSTEM

Filed Aug. 16, 1933

2 Sheets-Sheet 1



INVENTOR
E. BRUCE
BY *E. V. Briggs*
ATTORNEY

April 6, 1937.

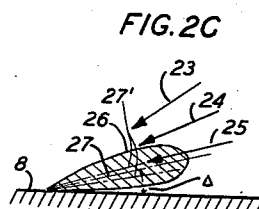
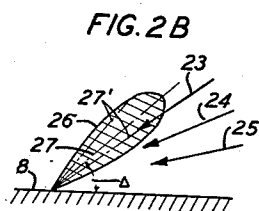
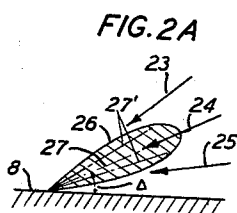
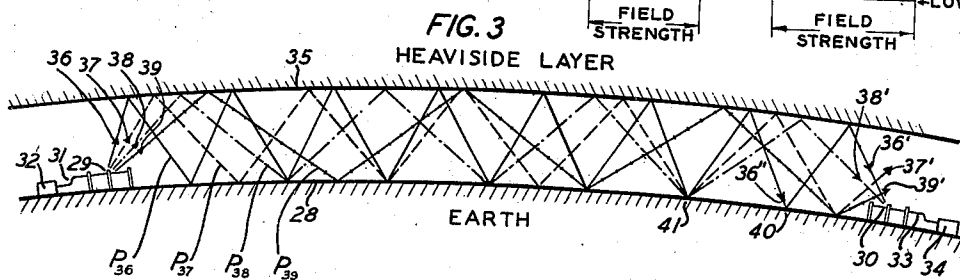
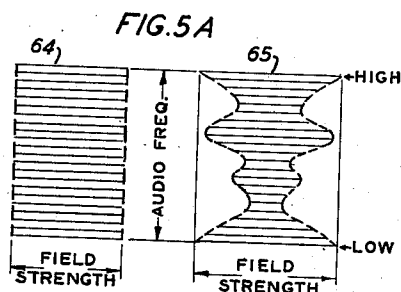
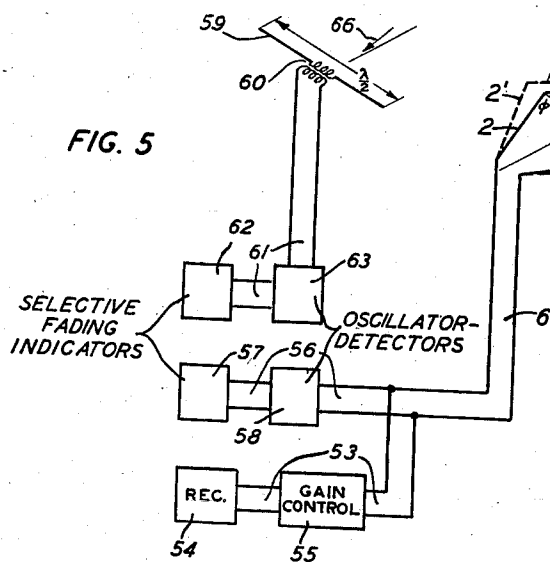
E. BRUCE

2,076,222

DIRECTIVE RADIO SYSTEM

Filed Aug. 16, 1933

2 Sheets-Sheet 2



INVENTOR
E. BRUCE
BY
E. V. Briggs
ATTORNEY

UNITED STATES PATENT OFFICE

2,076,222

DIRECTIVE RADIO SYSTEM

Edmond Bruce, Red Bank, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 16, 1933, Serial No. 685,340

22 Claims. (Cl. 250—11)

This invention relates to radio communication systems and more particularly to methods of and means for eliminating fading effects in radio communication.

As is well known, fading in radio reception varies at different frequencies and is ordinarily classified as either general or selective, the term "general" referring to similar fading at all frequencies in a band of frequencies containing the carrier and sidebands, and the term "selective" to unlike fading within this band. It is now more or less accepted that general fading occurs as a result of changes in the transmission medium or as a result of extremely small variabilities in the length of the various transmission paths which the waves travel in reaching the receiver and especially those which initially possess small length differences, these differences corresponding to radio frequency wave lengths. Selective fading is occasioned to some extent by a rapidly varying wave polarization and principally, applicant has discovered, by relatively small fluctuations in the length of the particular multiple paths which initially possess large differences in their respective lengths.

In the past various systems designed for overcoming general and/or selective fading have been employed with some success. In Patent 1,778,750 granted to me on October 21, 1930, there is disclosed a system designed especially for eliminating general fading and employing a gain control device; and in a copending application of J. S. Stone, Serial No. 460,172, filed June 10, 1930, a diversity system, designed to eliminate selective fading and utilizing phase shifters and differently directed unilateral antenna units, is described. It appears desirable, however, to eliminate fading, especially selective fading, in receiving systems now being used which comprise a single antenna having a directivity as great as is practically obtainable, and in future systems to receive radiant energy without fading effects utilizing a single, simple and inexpensive antenna unit and a minimum of equipment associated therewith.

It is one object of this invention to improve radio communication.

It is another object of this invention to eliminate general and selective fading in a simple, more economical and more satisfactory manner than heretofore achieved and at all times, substantially during the period of reception.

It is still another object of this invention to eliminate fading at a distance receiving station utilizing means at the transmitting station.

It is a further object of this invention to receive continuously the maximum amount of energy permissible without introducing objection-

able fading effects, at all times, substantially, during the receiving period.

According to one feature of this invention a major lobe of a directive receiving antenna, such as the rhombic antenna disclosed in my copending application, Serial No. 513,063, filed February 3, 1931, is steered or directed so as to select only one of several wave directions included in the same vertical plane. When the spacing between the adjacent incoming wave directions included in a wave cluster is less than the width of the lobe, as is usually the case, the lobe is steered so that an edge portion thereof includes an outermost, either the lowest or highest, wave direction and the radial portion containing the longest radius, or principal axis, avoids the cluster. Upon a material change in the outermost wave direction or in the spacing of the wave directions in the cluster, the lobe is redirected in accordance with the change and so as to achieve reception as at first obtained. Steering is accomplished by changing the value of an antenna dimension upon which the directive characteristic is at least partially dependent and, in the case of the rhombic antenna, by varying the side apex angle, or the side length, or the antenna height above ground. A fading indicator is associated with the directive antenna. For the purpose of easily determining when objectionable fading exists and also for insuring continuous maximum energy absorption by the directive antenna and at the same time minimum fading, a non-directive comparison antenna connected to another fading indicator is employed.

According to another feature of this invention a major lobe of a directive transmitting antenna is steered with respect to a particular receiving station so as to insure, at the receiving station, reception from one direction only. The transmitting antenna may also be steered so as to establish at the receiving point a field of maximum intensity when reception in one direction only is obtainable.

Additional objects and features of the invention will be apparent from the following detailed specification taken in connection with the accompanying drawings on which like reference numerals designate elements of similar function, and

Fig. 1 illustrates a rhombic antenna and one means for steering its major lobe;

Figs. 2A, 2B, and 2C illustrate the different positions with respect to an incoming wave cluster which may be assumed by the same major lobe of the antenna illustrated in Fig. 1;

Fig. 3 illustrates the method of eliminating fading at a distant receiving point utilizing means at the transmitting station;

Fig. 4 illustrates a rhombic antenna and a different means for steering its major lobe;

Fig. 4A is a plan cross-sectional view of one of the roller assemblies and supporting poles employed in the system of Fig. 4;

Fig. 5 illustrates a complete receiving system comprising a directive rhombic antenna and a comparison antenna; and

Fig. 5A illustrates typical indications as obtainable on the fading indicators employed in the system of Fig. 5.

Referring to Fig. 1 reference numeral 1 designates a rhombic antenna of the type disclosed in my copending application mentioned above, horizontally oriented so as to absorb horizontally polarized wave components. Each side 2 of antenna 1 has a length "l" approximately equal to its projection on the path or direction included in the vertical plane of wave propagation plus a half of the operating wave length " λ ", as described in my Patent 1,899,410 issued on February 28, 1933. The direction of extension of each leg or side 2 is such as to provide a distributed phase shift, with respect to a particular output point, for the elemental energies absorbed by the side. The vertical plane of wave propagation is defined as the plane passing through the transmitting and receiving points and the arc of the great circle connecting said points, and will hereafter be designated as the vertical incident plane.

References numerals 3, 4, and 5 designate resistances which constitute a far-end or terminating distributed impedance, the function of the terminating impedance being to render the antenna unilateral. For the purpose of overcoming undesirable capacity effects and also for promoting greater unidirectivity the terminals of the distributed impedance are separated as much as practicable by inserting resistance 3 in one far antenna side, resistance 5 in the adjacent far side and resistance 4 between these two sides at the far-end apex. When the power to be dissipated by the terminating impedance is large, as in the case of a transmitting antenna, an iron wire line may be employed in place of resistances 3, 4, and 5. The rear-end antenna terminals are connected by means of transmission line 6 to a translation device 7 which may be either a transmitter or receiver. The antenna 1 is supported at a distance H above ground 8 by means of guy wires 9, 10, and 11 and wooden poles 12, as will be explained in greater detail later. Numerals 13 designate insulators included between the antenna 1 and the guy wires 9, 10, and 11.

While the rhombic antenna described above is especially suitable for practising the invention it should be understood here that the invention is not to be limited to this type of antenna inasmuch as it will be apparent to those skilled in the art that other types of antennas including antennas arranged for absorption of vertically or circular polarized components may be successfully employed.

The directional characteristic, I_r , for antenna 1 is given by the following equation:

$$I_r = K \left[\sin \left(\frac{2\pi H}{\lambda} \sin \delta \right) \right] \cdot \left[\frac{\cos \phi}{1 - \sin \phi \cos \delta} \right] \cdot \left[\sin^2 \left(\frac{\pi l}{\lambda} (1 - \sin \phi \cos \delta) \right) \right]$$

Where I_r = current at the point connected to the translation device.

K = a constant.

λ = the operating wave length.

H = height of the antenna above ground — an antenna dimension.

δ = angle above the horizontal in the vertical incident plane of the incoming wave.

ϕ = one-half the side apex angle — an antenna dimension.

l = the length in wave lengths of one side of the rhombic antenna — an antenna dimension.

In the above equation there are four variables, three of which are the antenna dimensions H , l and ϕ and the other of which is the wave angle δ . The angle ϕ as used herein corresponds to the angle ϕ , as defined in applicant's above mentioned patent only when δ equals 0, that is, only when the direction of maximum antenna action is in the plane of the antenna conductors. When the path or direction of the desired wave intercepts the plane of the rhombic antenna and when the maximum direction of antenna action coincides with the path, the angle between each side conductor and the path of the wave, that is, the critical angle defined and designated ϕ in the above-mentioned patent, differs in value from ϕ as used herein and may be conveniently designated ψ . Also, for convenience the complement of ϕ may be designated s and the complement of ψ may be designated γ , ϕ being equal to ψ and s being equal to γ when δ equals zero. The lobe elevation angle, that is, the angle between the plane of the antenna conductors and the principal lobe axis or direction of maximum antenna action may be designated ω . ω equals δ when the principal lobe axis coincides with the arrival direction or path of the desired or maximum wave. See Figures 2A and 5.

Assuming a constant value for H , a value of l as given above and a single wave angle δ , it can be shown mathematically that, regardless of the value of H , ϕ equals the complement of δ when the principal axis or radius of the major lobe is a maximum obtainable and is in alignment with the incoming wave direction. Consequently, where antenna 1 is used for receiving purposes and there is only a single incoming wave direction having a known wave angle δ the antenna is preferably constructed so that ϕ equals $90^\circ - \delta$, for the purpose of obtaining maximum absorption. With a single incoming wave direction the small amount of selective fading, if any, is caused solely by polarization variations.

It has been found that an exceedingly large number of energized paths exists in the ether between the transmitter and receiver. A path is here defined as the course followed by a single wave of the signal energy. This signal energy emanates from the transmitting antenna in the form of a large number of waves, the number being dependent upon the sharpness of the directive major lobe of the antenna. These paths have, at the receiver, various downcoming wave directions which constitute, as termed herein, a wave fan or cluster. It has been found that the cluster spread, the spacing of the wave directions in said cluster and the angle between the mean or central direction in the cluster and the earth remain relatively constant during a reception period. Assuming two incoming wave directions in the vertical incident plane, which initially have

a large difference, say thirty-five miles, in their respective path lengths from the distant transmitter, selective fading occurs at an audible frequency corresponding to the difference, upon a fluctuation in the length of either of the two incoming waves. The fluctuation must, of course, be sufficient to effect a change in the phase relation of the waves traversing said paths. It is believed, contrary to the theory advanced by others, that the mere difference does not cause the transient or selective fade although it may cause a constantly increased intensity, that is a "peak", or a constantly decreased intensity, sometimes called a "depression", at the frequency in question as compared to the intensities at other closely adjacent frequencies.

In order to overcome the selective fade the major lobe is deliberately steered as explained hereinafter so as to avoid all except one, substantially, of the incoming wave paths included in the cluster. When the spacing between the incoming wave direction is closer than the width of the major lobe, maximum absorption is unattainable inasmuch as the principal axis must then be directed away from the cluster. In such a case reception is accomplished, in effect, by aligning a minor or subordinate axis of the major lobe with an outermost wave direction, and preferably the longest minor axis consistent with reception in a single wave direction. The wave direction is in effect included in an edge portion of the lobe, an edge portion being here defined as any lobe portion exclusive of the radial portion containing the principal axis.

From the above equation it will be apparent that by maintaining any two of the three variables H , l and ϕ constant, the angle in the incident plane included between the principal lobe axis and the earth's surface or the plane of the antenna conductors, may be controlled by varying the third variable. Thus, the major lobe may be steered by varying H , l or ϕ . Moreover, undesired minor lobes may be eliminated by slightly varying one of the three dimensions. Varying ϕ H or l an amount sufficient to properly direct the lobe does not change the relation between the side length " l " and its projection on the wave path included in the incident plane from the optimum value stated above.

Referring again to Fig. 1 the movable guy wires 10 connected to the side apex antenna angles are each associated with a pulley 14 and terminated in a counterweight 15, each pulley 14 being supported at the top of a pole 12. The movable guy wire 11 connected to the far-end apex angle passes over pulley 16 which is supported on another pole 12 and terminates in winch 17. A reversible motor 18 is employed for driving the winch 17. A counterbalanced winch 19 is associated with weight 20 by means of rope 21 and pulley 22, for the purpose of governing the speed of winch 17 and permitting the use of a small motor. The motor 18 is preferably controlled from a distant point at which point an indicator, not illustrated, is provided for automatically indicating the value of the side apex angle ϕ . An automatic safety device, also not illustrated, is provided at the control point for limiting the movement in either direction of the guy wire 11. Numerals 23, 24, and 25 designate wave directions included in the vertical incident plane and incoming to antenna 1 when the antenna is employed for receiving purposes.

Referring to Figs. 2A, 2B, and 2C, reference numerals 26 designate the same major lobe of the

directive antenna 1 and numerals 23, 24, and 25 designate, as in Fig. 1, the downcoming wave directions which constitute an incoming wave cluster. Numerals 27 designate the principal lobe axes and numerals 27' designate minor or subordinate axes.

When the system of Fig. 1 is employed for receiving energy, elimination of fading is achieved as follows:

The side apex angles of the rhombic antenna 1 are, if necessary, first slightly varied by means of motor 18 to eliminate minor lobes. They are then similarly varied an amount sufficient to cause the sides 2 to assume, for example, the positions indicated by dotted lines 2', and principal axis 27 of the major lobe 26 to align with an incoming wave direction as, for example, direction 24. If the spacing between wave directions 23, 24, and 25 is wider than the width of the lobe, as shown in Fig. 2A, the principal axis 27 is maintained aligned with the chosen wave direction, the lobe being redirected whenever necessary in accordance with the directive changes of said wave direction. If the wave direction spacing is less than the lobe width, as shown in Figs. 2B and 2C, the side apex angles are further varied so as to cause the major lobe to include only one outermost wave direction of suitable field strength, for example, direction 23 in Fig. 2B or direction 25 in Fig. 2C. Stated differently, the lobe is steered so that only one minor axis 27' aligns with an incoming wave direction. In addition the lobe is caused to intercept the included wave direction at a point as close as practicable to the principal axis 27 and, at the same time, to avoid the adjacent wave direction 24, as explained above. In practice it has been found that weak waves having extreme outermost positions in the cluster and sometimes included in the edge lobe portion along very short minor axes do not materially interfere with the reduction of selective fading. Obviously, the lobe may be steered so as to approach the chosen outermost direction from a point entirely outside, as well as from a point within, the cluster.

Referring to Fig. 3, reference numeral 28 designates the surface of the earth included between a steerable transmitting rhombic antenna 29, such as that illustrated in Fig. 1, and a distant receiving rhombic antenna 30 which is preferably steerable. Antenna 29 is connected by means of line 31 to a transmitter 32 and antenna 30 is connected by means of line 33 to a receiver 34. Numeral 35 designates a reflecting surface such as the Heaviside layer. For convenience only two reflecting surfaces, the earth and the Heaviside layer, are illustrated although it is now more or less established that other reflecting surfaces or layers exist. The transmitted major lobe of antenna 1 may be steered, as explained in connection with Fig. 1, so as to cause its principal axis to align with any one of the outgoing wave directions 36, 37, 38 or 39.

Reference characters P_{36} , P_{37} , P_{38} , and P_{39} designate paths in the ether which have, respectively, at the transmitter the outgoing directions indicated by arrows 36, 37, 38, and 39 and near the receiver the directions indicated by 36', 37', 38', and 39'. Directions 36' and 38', it will be noted, are incoming to antenna 30, so that paths P_{36} and P_{38} actually include or connect antennas 29 and 30. On the other hand directions 37' and 39' avoid antenna 30 so that paths P_{37} and P_{39} do not constitute paths between these antennas. As illustrated, and as is now well understood, several reflections occur in the energized paths P_{36} , P_{37} , 75

P₃₈, and P₃₉. It may be noted here that regardless of the degree of concentration obtained in radiating energy into the ether it has been found that, invariably, several distinct paths become energized as a result of the radiation.

Assuming now that the outgoing direction 37 aligns with the principal axis and outgoing directions 36 and 38 align with an upper minor and a lower minor axis of the lobe, respectively, path P₃₉ being unenergized, any small variability in the lengths of the paths P₃₆ or P₃₈ traced by the waves will, as explained above, result in selective fading. To overcome such fading, the major lobe of the transmitting antenna is directed so that its principal axis coincides with outgoing direction 38 and the two said minor axes with directions 37 and 39, path P₃₆ now being unenergized. With this adjustment, only a single incoming wave direction 38', which also corresponds to the direction of maximum field strength, is effective at the receiving antenna 30. As already explained, the reception of a single incoming wave direction at the receiver insures the elimination of selective fading. The steerable receiving antenna 30 is preferably adjusted for optimum reception of the single incoming wave direction 38'.

The steerable transmitting antenna 29 employed in the system of Fig. 3 is also useful for other purposes than the elimination of selective fading. Often the condition of the transmitting medium is such that reception during certain periods is accomplished at antenna 30 only when energy is transmitted from antenna 29 in a particular direction as, for example, direction 36. In such a case, the principal axis of the major lobe is caused to align with the particular or free direction 36 for the purpose of establishing a field of maximum intensity at antenna 30. The energy transmitted along impeded path P₃₈ does not cause selective fading since it does not reach antenna 30.

Numeral 40 designates, by way of further explanation, a point at which reception occurs in one direction only, even when several energized paths exist in the ether. To transmit to point 40, the principal lobe axis should be aligned with a path having an incoming direction 36'' at point 40. Numeral 41 designates, by way of comparison, a receiving point at which, ordinarily, extreme selective fading occurs.

Referring to Fig. 4, an alternative arrangement for steering the major lobe of a rhombic antenna, utilizing means for varying the antenna height, is illustrated. The rhombic antenna 1 is similar to that illustrated in Fig. 1 and is supported by means of guy wires 42 each connected to an arm 43 which in turn are movably mounted on poles 12. The four arms 43 are each connected to a pair of rollers 44, each pair being arranged to travel vertically in a track 45 included in pole 12, as shown in Fig. 4A. Reference numeral 46 designates ropes, preferably non-conductive, which are wound on drum 47, the supporting structure for which is not illustrated. Each of ropes 46 is connected over pulleys 48 and 49 to a different arm 43. Pulley wheels 50, the supports for which also are not illustrated, are provided for the purpose of insuring proper travel of the ropes 46 associated with the side apex antenna angles. Reference numerals 51 designate counterweights which are connected by means of ropes 52 to arms 43. These counterweights assist in lowering the antenna 1. Ropes 46 and 51 are securely fastened to arms 43. The reversible motor 18 actuates drum 47. Safety de-

vices, not illustrated, are preferably provided for limiting in both directions the movement of drum 47.

In operation, the motor 18, which is controlled from a distant point, as in the system of Fig. 1, is caused to move the transmitting or receiving antenna 1 to a position as, for example, that illustrated by dotted lines 2'', at which position the direction of the antenna major lobe is such as to eliminate selective fading. Obviously, the same rhombic antenna may be equipped, if so desired, with both steering means, as illustrated in Figs. 1 and 4, the means being arranged for independent or simultaneous manipulation. Furthermore, means for varying the side length "T" may be associated with the rhombic antenna, for lobe steering purposes.

Referring to Fig. 5 a receiving system especially useful in systems employing wobbled wave transmission, such as disclosed in Patent 1,454,532 granted to W. E. Beatty on May 8, 1923 is illustrated. Reference numeral 1 designates a horizontal rhombic antenna, which is similar in construction to that illustrated in Fig. 1 and the major lobe of which is steered by varying the side apex angle ϕ . Antenna 1 is connected by means of transmission lines 6 and 53 to a receiver 54 through gain control device 55 which may be of any conventional type, as for example, the type disclosed in Patent 1,778,750, mentioned before. The antenna 1 is also connected by means of transmission lines 6 and 56 to a selective fading indicator 57 through oscillator-detector 58 which is employed for obtaining a wobbled audio wave. Reference numeral 59 designates a horizontal comparison non-directive half-wave length antenna which is connected by means of transformer 60 and line 61 to a selective fading indicator 62 through oscillator-detector 63. The fading indicators are preferably of the cathode ray type. Each indicator is arranged to present a rectangular pattern or picture when selective fading does not exist, the width of the pattern being proportional to the received field strength and the height proportional to audio frequency variation, as illustrated in diagram or indication 64 of Fig. 5A. Numeral 65 designates a typical cathode ray pattern obtained when severe selective fading exists. Reference character 66 designates the path or direction of the desired wave at the antennas 1 and 59, and reference character α designates the angle between the path 66 and the horizontal plane.

In operation wobbled waves traveling in the vertical incident plane and having a downcoming direction 66 are received from the distant station by antennas 1 and 59 and conveyed to the associated oscillator-detector, and to receiver 54. The detected wobbled waves are supplied, respectively, to indicators 57 and 62. If the indication on indicator 62 is rectangular, selective fading is not present and presumably only a single incoming wave direction is being intercepted by both antennas. In such a case, the major lobe of the rhombic antenna is steered so that its principal axis aligns with the single incoming direction whereby maximum absorption is achieved. If the indication on indicator 62 is not rectangular selective fading is present and the major lobe of the rhombic antenna 1 is steered so as to accept one wave direction, that is, so as to produce a rectangular indication on indicator 57 and stabilized reception by receiver 54. The observer watches both indicators simultaneously.

The comparison system comprising antenna 59 and associated indicator 62 is not essential. It does provide, however, a constant and convenient indication of the fading during the time the rhombic antenna is being adjusted and during which time the fading may and often does, disappear. It also enables the operator to obtain, continuously, the maximum permissible absorption of wave energy without introducing selective fading; and to achieve fading elimination and optimum operation without assistance from the transmitter station. To illustrate, after the rhombic antenna has been once adjusted the fading may materially decrease or entirely disappear. The indicator 62 reveals this changed condition and the operator moves the lobe nearer to the mean or central direction in the cluster for the purpose of aligning the same wave direction with a longer minor axis; and, in the case of complete fading disappearance, so as to align it with the principal axis.

The system just described, as well as the system of Figs. 1 and 4 functions to eliminate to some extent, general fading as well as selective fading. This is true since only one wave direction is accepted; and general fading is caused in part by small variabilities in the lengths of the multiple paths which initially possess small differences, comparable to radio frequency wave lengths, in their respective path lengths. The gain control 55 functions, as explained in Patent 1,778,750 above mentioned, to further eliminate general fading as occasioned primarily by changes in the transmission medium. Obviously, for the purpose of indicating selective fading, a carrier having a characteristic other than a wobbled characteristic as, for example, a tone or pulse characteristic and indicators other than cathode ray indicators may be employed.

The invention described herein has been employed with very satisfactory results. In one system waves have been transmitted on a wave length of 20.78 meters from station GBW located at Rugby, England and received at Holmdel, New Jersey, by a system similar to that illustrated in Fig. 5, and in which the angle ϕ was varied between 60° and 70° approximately. Fig. 5A, in fact, illustrates typical indications which were received, indication 62 being obtained on the indicator associated with the rhombic antenna and indication 63 being obtained simultaneously on the fading indicator associated with the comparison antenna. It is interesting to note that selective fading elimination increased rapidly as the degree of fading became greater.

While the invention has been described in connection with certain embodiments it should be understood that it is not to be limited to these embodiments. Obviously, other transmitting or receiving antennas, either vertically or horizontally positioned and arranged to transmit or receive vertically or horizontally polarized wave components, may be employed; and means for steering the major lobe other than those described above may of course be employed. Moreover, selective fading and other interference as occasioned by the existence of wave clusters in incident planes other than the vertical incident plane as, for example, clusters included in a horizontal incident plane and resulting from the passage of the waves through a shadow wall, may be successfully eliminated in accordance with this invention.

What is claimed is:

1. A method of radio communicating which

comprises energizing a plurality of paths of different lengths in the transmission medium included between two stations and continuously confining the communication to a single path through said medium, substantially.

2. A method of radio communication which comprises directing energy toward a reflecting surface included effectively between two stations, whereby the energy travels between said stations along paths of different lengths, and receiving at one of the stations, and during substantially the entire communicating period, energy propagated along a single path.

3. A method of radio communicating which comprises directing energy toward the Heavyside or similar layer in a plane containing a distant receiving station and maintaining established at the receiving station, and at all times substantially during the communicating period, a single incoming radio field.

4. A method of improving radio communication between two stations in a system comprising a directive transmitting antenna, utilizing means for adjusting the position of a major lobe of the directive characteristic of said antenna, which comprises including in said lobe only one path of propagation having a direction incoming to the receiving station, substantially, and, upon a material directive change in said path at the receiving station, again including in said lobe only one path having a direction incoming to the receiving station.

5. A method of improving radio communication between two stations in a system comprising a directive receiving antenna, utilizing means for adjusting the position of a major lobe of the directive characteristic of said antenna, which comprises positioning said lobe so as to include only one energized path of propagation having a direction incoming to said antenna and, upon a material directive change in said path at said antenna, repositioning said lobe so as to again include only one energized path having a direction incoming to said antenna.

6. A method of stabilizing radiant energy absorption by a directive antenna, utilizing means for steering a major lobe of the directive characteristic of said antenna in a plane containing an incoming wave cluster, which comprises aligning one lobe axis only with an incoming wave direction substantially.

7. A method of stabilizing radiant energy absorption by a directive antenna, the effective receiving directions of which are dependent upon at least one adjustable antenna dimension, which comprises adjusting said dimension to secure reception in only one direction of wave propagation, substantially, included in an incoming wave cluster and, upon a change in said propagation direction, again adjusting said dimension to secure reception as at first obtained.

8. A method of eliminating fading in a system comprising a receiver connected to a directive antenna, a major lobe of the directive characteristic of which is wider than the spacing between adjacent wave directions in an incoming wave cluster, utilizing means for moving said major lobe, which comprises including only an outermost wave direction in an edge lobe portion while excluding said cluster from the remaining larger lobe portion.

9. A method of eliminating selective fading in a radio receiving system comprising a receiver connected to a directive antenna, utilizing means for varying at least one dimension of said an-

tenna upon which the directive characteristic is dependent which comprises varying said dimension an amount sufficient to eliminate undesired minor lobes of the antenna directive characteristic, and further varying said dimension to exclude all except one wave direction included in an incoming wave cluster.

10. A method of eliminating fading in a radio receiving system comprising a directive antenna connected to a receiver, utilizing means for steering a major lobe of the directive characteristic of said antenna in a plane containing an incoming wave cluster, the width of the major lobe being greater than the spacing of the wave directions in said cluster, which comprises causing the principal lobe axis to avoid said cluster and moving said lobe so as to include only an outermost wave direction of said cluster, substantially.

11. A method of reducing selective fading in a system comprising a translation device connected to a horizontal rhombic antenna, the direction of a major lobe of the directive characteristic of which is dependent upon certain antenna dimensions including the antenna height above ground and the value of the side apex angles, which comprises changing the value of at least one of the above dimensions an amount sufficient to receive only one suitable wave included in a wave cluster and upon a material change in said wave cluster, again changing one of the above dimensions an amount sufficient to compensate for said change.

12. A method of receiving wobbled radiant energy without substantial fading, utilizing a directive antenna connected to a receiver and through an oscillator-detector to a cathode ray fading indicator, the major lobe of the directive characteristic of said directive antenna being wider than the spacing between adjacent wave directions in an incoming wave cluster, means for moving said major lobe and a comparison antenna connected through a second oscillator-detector to a second cathode ray fading indicator, which comprises simultaneously observing the indications of said indicators to determine the fading condition, moving said lobe so as to obtain maximum reception and minimum fading, substantially, as indicated by the first indicator and upon a material change in the indication on one of the indicators again moving said lobe so as to obtain maximum reception without fading.

13. In a radio system, a directive rhombic antenna having sides greater than a half-wave length, said antenna having the principal axis of its major directive lobe included in a plane perpendicularly related to the plane of the antenna and containing one antenna diagonal, and means for varying one of the antenna dimensions on which the position of its major lobe in said first-mentioned plane is dependent.

14. In a radio system, a directive rhombic antenna, each leg of which is approximately a half wave-length longer than its projection on the path of propagation, and means for simultaneously and similarly changing its side apex angles.

15. In a radio system, a directive horizontal rhombic antenna, each side of which is equal to a half wave-length plus the projection of the side on the path of wave propagation, said antenna being positioned so that its operation is affected by the ground, and means for adjusting the antenna height above ground.

16. In a radio receiving system, a uni-directional rhombic antenna each leg of which is approximately a half wave-length longer than its projection on the path of wave propagation, means for adjusting the direction of a major lobe of its directive characteristic, said means being adjusted so that said lobe includes only one of several wave paths in an incoming wave cluster.

17. In a radio receiving system, a rhombic antenna, means for adjusting the position of the major lobe of its directive characteristic, a first fading indicator, a receiver, a gain control device, said antenna being connected to said first indicator and through said gain control device to said receiver, a non-directive antenna positioned relatively close to said rhombic antenna, a second fading indicator, said non-directive antenna being connected to said second indicator, the position of said lobe being dependent upon the indications received on both indicators and such as to receive a maximum amount of energy without fading.

18. A method of receiving radiant energy without substantial fading, utilizing a translation device connected to a directive antenna and means for varying the position of a major lobe of the directive characteristic of said antenna, which comprises including in said lobe at all times substantially only a single energized path of wave propagation and absorbing from the wave corresponding to said path a maximum amount of energy.

19. A method of improving radio communication between two stations separated by a medium in which several paths of different lengths are energized by one of the stations, which comprises receiving at any given instant at the other station energy propagated over only one of said paths and compensating for intensity variations in said energy during the communication period.

20. In a radio system, a unidirectional rhombic antenna comprising four conductors having their directions of maximum radiant action superimposed in effect in a plane perpendicularly related to the plane of the antenna and containing one diagonal of the antenna, and means associated with the antenna for changing in said first-mentioned plane the resulting direction of maximum radiant action of the antenna.

21. In a radio system, a directive antenna comprising two angularly related conductors, said antenna having its direction of maximum radiant action included in a plane perpendicularly related to the plane of the antenna and containing the bisector of the angle formed by said conductors, and means for changing in said first-mentioned plane the direction of maximum radiant action.

22. In a radio system, a directive antenna connected to a translation device and comprising a pair of angularly related conductors positioned in the same plane, means for changing the angle between said conductors, said angle being adjusted so that the length of each conductor is approximately a half wave-length greater than the projection of the conductor on the path or direction of the desired wave and so that the angle between said path and said plane is approximately equal to one-half the angle between said conductors.

EDMOND BRUCE.