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ANTENNA FOR RADIATING CIRCULARLY POLARIZED WAVES

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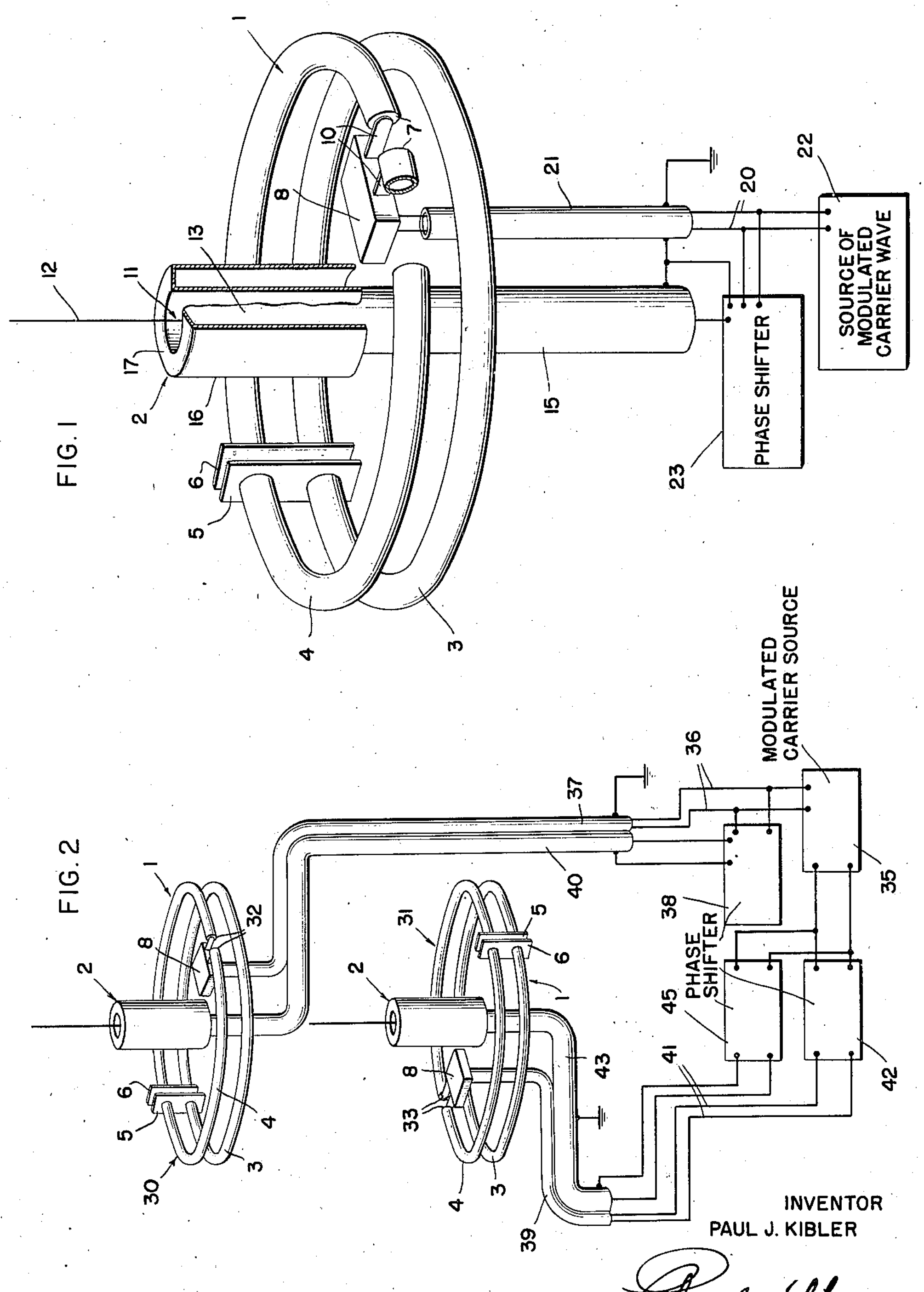

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ANTENNA FOR RADIATING CIRCULARLY POLARIZED WAVES

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This invention relates generally to high frequency antennae, and more particularly relates to an antenna system arranged to operate on circularly polarized waves so that its horizontal field strength pattern closely approaches a circle.

For the transmission of television signals it is conventional practice in this country to radiate a modulated carrier wave which is horizontally polarized. In England vertical polarization of a carrier wave modulated by a composite television signal is preferred. However, whether the modulated carrier wave be horizontally or vertically polarized, interference between the direct ray and a reflected ray cannot be eliminated. In general, a carrier wave reflected from any plane surface will have its amplitude and phase changed depending upon the dielectric constant of the reflecting surface and the angle of incidence of the wave. As long as the angle of incidence of the reflected wave is not too large, the phase of a wave polarized in the plane of incidence remains unchanged upon reflection, while the phase of a wave polarized perpendicularly to the plane of incidence is reversed. When the angle of incidence exceeds a certain value, which depends upon the dielectric constant of the reflecting surface, the phase angle is reversed whether the wave is polarized in the plane of incidence or normal thereto.

It will be appreciated that a modulated carrier wave may be reflected by a horizontal surface, that is by the surface of the earth or by water, as well as by vertical surfaces, such as buildings and other vertical structures which may be arranged between the transmitter and the receiver. Thus, no matter whether a horizontally polarized or a vertically polarized carrier wave is transmitted, reflection of the wave will usually take place, and subsequently the response curve of the receiver will be a function of the frequency due to the difference in phase between the direct ray and the reflected ray.

It has been suggested to radiate a modulated carrier wave which is circularly polarized. Under usual conditions a circularly polarized wave will reverse its sense of rotation upon reflection. It is well understood in the art that a circularly polarized wave may be considered as the resultant of two waves polarized linearly in a direction normal to each other and having a phase difference in time of 90 degrees. Hence, a circularly polarized wave may be considered as being composed of a horizontally polarized and a vertically polarized wave. Upon reflection on a flat surface one of the component waves will have its phase reversed, while the phase of the other component wave remains unchanged with the effect that the sense of rotation of the reflected circularly polarized wave is reversed.

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Thus it is possible to radiate a modulated carrier wave which is circularly polarized and which has a predetermined sense of rotation. When the receiver is arranged to receive only circularly polarized waves having the predetermined sense of rotation, a deflected wave will not be received by such a receiver. The transmission of signals by means of a circularly polarized carrier wave also has other advantages as will appear hereinafter.

It is usually desired to radiate a circularly polarized wave in all horizontal directions. However, a conventional antenna system comprising two dipole antennae displaced by 90 degrees from each other and energized with a 90 degrees phase shift with respect to each other will not radiate a circularly polarized wave uniformly in all horizontal directions. Strictly speaking, a circularly polarized wave will only be radiated in the direction of a plane. Accordingly, a conventional antenna system can not be used for radiating a circularly polarized modulated carrier wave into a large area as required for the transmission of television signals.

It is furthermore desirable to utilize a directive antenna so that the energy radiated from the antenna has a maximum in the horizontal direction and a minimum in the vertical direction. Thus, a directive radiating system preferably should have a horizontal field strength pattern which approaches a circle so that a large area may be covered as uniformly as possible by one transmitting antenna.

It is an object of the present invention, therefore, to provide a high frequency antenna system suitable for operation on circularly polarized waves.

Another object of the invention is to provide a high frequency directive antenna system which will radiate a circularly polarized wave in all horizontal directions with a maximum field strength in the horizontal plane.

A further object of the invention is to provide a high frequency directive antenna system or antenna array arranged for operation on circularly polarized waves and having a field strength pattern in the horizontal plane which closely approaches a circle.

In accordance with the present invention, there is provided a high frequency directive antenna system comprising a horizontal radiator including a plurality of conductors arranged horizontally with a common axis, connected together at their ends and forming each a peripherally incomplete loop. One of the conductors is open at its mid point to provide a pair of terminals. The horizontal radiator has an effective electrical length which is substantially equal to one-half wavelength at the high frequency. A first transmission line is connected to the terminals for transfer of high frequency energy between the horizontal radiator and the first transmission line. There is also provided a vertical radiator including a dipole conductor arranged vertically along the common axis of the horizontal radiator. The vertical radiator has an effective electrical length which is substantially equal to one-half the wavelength at the high frequency. Finally, a second transmission line is provided which is connected to the vertical radiator for transfer of high frequency energy between the vertical radiator and the second transmission line.

For a better understanding of the invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing, Fig. 1 is a perspective view, with parts broken away, of a high frequency antenna system embodying the present invention, while Fig. 2 is a perspective view of an antenna array having two stacked antenna systems in accordance with the invention.

Referring now more particularly to Fig. 1 of the drawing, there is illustrated a high frequency directive antenna system comprising a horizontal radiator 1 and a vertical radiator 2. Horizontal radiator 1 is essentially a folded half-wave dipole bent into a circle to form two peripherally incomplete loops or conductors 3 and 4. The open ends of conductors 3 and 4 are connected together electrically by capacitance plates 5 and 6. Accordingly, conductors 3 and 4 are capacitance loaded at their ends to secure a more nearly uniform current distribution. As illustrated in Fig. 1, conductors 3 and 4 are arranged horizontally with a common vertical axis along which vertical radiator 2 is arranged. Conductors 3 and 4 have been illustrated as tubes of toroidal shape having equal inner diameters. However, it is to be understood that conductors 3 and 4 may also have different inner diameters and that more than two conductors may be provided. Conductor 4 is open at its mid point to form a pair of input terminals 7 which are connected to impedance matching box 8 by two parallel conductors 10.

Conductors 3 and 4 with their capacitance plates 5 and 6 form a horizontal radiator having an effective electrical length which is substantially equal to one-half the wavelength of the modulated carrier wave to be transmitted or received. Actually the effective electrical length of each loop 3 and 4 is substantially equal to one-half the wavelength of the carrier.

Vertical radiator 2 may consist of a conventional vertical half-wave dipole. Preferably, however, vertical radiator 2 consists of a so-called coaxial vertical dipole or sleeve antenna. Thus, vertical radiator 2 includes a coaxial transmission line 11 comprising center conductor 12 and cylindrical conductor 13 coaxial with center conductor 12. Coaxial conductor 11 may form an extension of a low loss coaxial transmission line 15. It will be seen that center conductor 12 extends beyond cylindrical conductor 13. Vertical radiator 2 further includes outer conductor 16 in the form of a large pipe or cylinder surrounding cylindrical conductor 13 and connected at 17 to the free end of cylindrical conductor 13. Accordingly, cylindrical conductor 13 and outer conductor 16 together form a sleeve or a collar.

The effective electrical length of vertical radiator 2 is also substantially equal to one-half the wave-length of the modulated carrier wave to be transmitted or received. The length of center conductor 12 extending beyond cylindrical conductor 13 and outer conductor 16, preferably equals the length of outer conductor 16, each being individually equal in length to one-quarter the wave-length of the carrier wave to be transmitted or received.

The capacitance formed by plates 5 and 6 may be made adjustable to vary the resonant frequency of horizontal radiator 1. Accordingly, it will be seen that the physical length of each loop 3 and 4 will be less than one-half the wave-length of the carrier wave to be radiated. In some cases it may also be advantageous to provide a capacitance between input terminals 7 of conductor 4 for adjusting the resonant frequency of horizontal radiator 1. Vertical radiator 2 should be arranged along the common vertical axis of conductors 3 and 4. However, vertical radiator 2 need not be arranged symmetrically with respect to a horizontal plane passing between conductors 3 and 4.

Vertical radiator 2 is, preferably, connected to a coaxial transmission line 15. Horizontal radiator 1 is connected through impedance matching box 8 to parallel wire line 20 shielded by cylindrical conductor 21 which is grounded as shown. Impedance matching box 8 may, for example, consist of a quarter wave transmission line of suitable characteristic impedance or of a network consisting of lumped elements and matches the terminating impedance of parallel wire line 20 and the input impedance of horizontal radiator 1 which may be of the order of 35 ohms.

Both horizontal radiator 1 and vertical radiator 2 are connected to a source of a modulated carrier wave indicated schematically at 22. Parallel wire line 20 is directly connected to source 22, while coaxial transmission line 15 is connected to source 22 through phase shifter 23. Phase shifter 23 is arranged so that the modulated carrier wave from source 22 is transferred to vertical radiator 2 with a 90 degrees phase shift in time with respect to the modulated carrier wave transferred to horizontal radiator 1. Provided the length of parallel wire line 20 is equal to the length of coaxial transmission line 15 between source 22 and their respective radiators 1 and 2, phase shifter 23 should shift the phase of the modulated carrier wave by 90 degrees. However, the electrical length of parallel wire line 20 need not be the same as that of coaxial transmission line 15. In that case phase shifter 23 should be arranged so that the phase of the wave transferred to vertical radiator 2 has a 90 degrees phase-shift in time with respect to the phase of the wave transferred to horizontal radiator 1.

In order to radiate a circularly polarized wave from the antenna system of Fig. 1, the amplitudes of the waves transferred to horizontal radiator 1 and to vertical radiator 2 should be equal. Actually, in view of the fact that the radiation resistance of radiators 1 and 2 may be different, the wave radiated from horizontal radiator 1 should have the same amplitude as the wave radiated from vertical radiator 2.

Horizontal radiator 1 radiates a horizontally polarized wave into space, while vertical radiator 2 radiates a vertically polarized wave. Both horizontal radiator 1 and vertical radiator 2 radiate energy predominantly in a horizontal plane. It is well understood in the art that when a horizontal radiator is fed with a wave that is 90 degrees out of phase in time with respect to that of the wave fed to a vertical radiator, a circularly polarized wave is radiated into space. The field strength pattern of horizontal radiator 1 closely approaches a circle as is well understood in the art. Consequently, the field strength pattern of the antenna system comprising horizontal radiator 1 and vertical radiator 2 will be substantially uniform in all horizontal directions. Furthermore, the antenna system of the invention will radiate a substantially circularly polarized wave in all horizontal directions.

The antenna system illustrated in Fig. 1 has been described particularly as a transmitting antenna system. However, it is to be understood that the antenna system of Fig. 1 may also be employed with receiving equipment. It is immaterial whether the antenna system of the invention is used for radiating energy into space or for abstracting energy from an incident high frequency electromagnetic wave.

A transmitting antenna in accordance with the present invention which radiates a circularly polarized wave substantially uniformly in all horizontal directions may be used with advantage in a television system. In densely populated areas reflections of the modulated carrier wave from buildings and other vertical structures cause blurring of the reproduced television picture in view of the difference in time between the direct and a reflected wave. This drawback may be substantially eliminated by radiating a circularly polarized wave having a preferred sense of rotation. Since the sense of rotation of a circularly polarized wave is reversed when the wave is reflected, reception of the reflected wave may be prevented by providing a receiver circuit which is only responsive to the preferred sense of rotation of the circularly polarized wave. A preferred receiver circuit which is only responsive to circularly polarized waves having a predetermined sense of rotation is described in United States Patent No. 2,350,331, granted on June 6, 1944, to H. Salinger, and assigned to the same assignee as is this application.

When reflection of the received wave from buildings and other vertical structures is too infrequent to cause appreciable distortion of the received signal, a circularly polarized wave may also be used for improving the signal to noise ratio at the receiver. To this end the receiver antenna may consist of a conventional half-wave dipole. The dipole antenna may be oriented in any direction in a plane normal to the line connecting transmitter and receiver without loss of signal strength. Hence, the receiving antenna may be arranged in a direction so that the effect of local noise sources is minimized.

The phase and the amplitude of the wave radiated by horizontal radiator 1 may not be exactly equal in all horizontal directions. Accordingly, the wave radiated in certain horizontal directions by the antenna system of Fig. 1 may be elliptically polarized instead of circularly polarized. The wave radiated by the antenna system of Fig. 1 is only circularly polarized when the amplitudes of the modulated carrier wave radiated from horizontal radiator 1 and vertical radiator 2 are equal and when the phase difference in time between the two waves radiated from radiators 1 and 2 is 90 degrees. In order to overcome this drawback, it may be advantageous to use an antenna array such as shown in Fig. 2.

Referring now to Fig. 2, in which like components are designated by the same reference numerals as were used in Fig. 1, there is provided an antenna array comprising two stacked antenna systems 30 and 31. Antenna systems 30 and 31 each comprise a horizontal radiator 1 and a vertical radiator 2 which may be identical to radiators 1 and 2 of Fig. 1. However, input terminals 32 of antenna system 30 are arranged opposite to input terminals 33 of antenna system 31 in a vertical plane passing through the common vertical axis of antenna systems 30 and 31.

Both antenna systems 30 and 31 are connected to modulated carrier source 35. To this end parallel wire line 36, which may be shielded by grounded tube 37, interconnects modulated carrier source 35 to horizontal radiator 1 of antenna system 30. Phase shifter 38 coupled to modulated carrier source 35 is connected to coaxial transmission line 40 for transferring high frequency energy from source 35 to vertical radiator 2 of antenna system 30. Phase shifter 38 is arranged so that the phase of the high frequency energy transferred to vertical radiator 2 has a 90 degrees phase shift in time with respect to that of the energy transferred to horizontal radiator 1.

The high frequency energy transferred to horizontal radiators 1 of antenna systems 30 and 31 should be in phase, as well as the energy transferred to vertical radiators 2 of antenna systems 30 and 31. Accordingly, parallel wire line 41, which may be shielded by grounded tube 39, connects modulated carrier source 35 to horizontal antenna 1 of antenna system 31 through phase shifter 42. In case parallel wire lines 36 and 41 have the same length or differ in length by a full wavelength of the modulated carrier wave, a phase shifter such as 42 is not required. Coaxial cable 43 connects modulated carrier source 35 to vertical radiator 2 of antenna system 31 through phase shifter 45. Phase shifter 45 is arranged so that the energy fed to vertical radiator 2 of antenna system 31 is 90 degrees out of phase in time with respect to the phase of the energy transferred to horizontal radiator 1 of antenna system 31.

By arranging input terminals 32 and 33 opposite to each other the slight difference in phase or amplitude of the wave radiated by horizontal radiators 1 in certain horizontal directions is equalized. Accordingly, the wave radiated by the antenna array of Fig. 2 should be circularly polarized in all horizontal directions with an almost perfect circular field strength pattern. The distance between antenna systems 30 and 31 is not very critical. Preferably, this distance is of the order of a wavelength of the modulated carrier.

It is also feasible to utilize an antenna array comprising more than two stacked antenna systems such as 30 and 31. In that case the input terminals, such as 32 and 33, of the antenna systems should be arranged symmetrically about the common vertical axis of the antenna systems and in a vertical plane passing through the common axis. In other words, the input terminals of adjacent antenna systems should be arranged opposite to each other. However, for most practical purposes an antenna array comprising two stacked antenna systems, as illustrated in Fig. 2, will be sufficient for radiating a wave which is circularly polarized in all horizontal directions with a substantially circular field strength pattern.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A high frequency directive antenna array comprising two stacked antenna systems each having a horizontal radiator including a plurality of conductors arranged horizontally with a common vertical axis, connected together at their ends and forming each a peripherally incomplete loop, one of said conductors being open at its mid point to provide a pair of terminals, said horizontal radiator having an effective electrical length substantially equal to one-half wavelength at said high frequency, a first transmission line connected to said terminals for transfer of high frequency energy between said horizontal radiator and said first line; each of said two antenna systems further having a vertical radiator including a dipole conductor arranged vertically along said common axis, said vertical radiator having an effective electrical length substantially equal to one-half said wavelength, and a second transmission line connected to said vertical radiator for transfer of high frequency energy between said vertical radiator and said second line, the terminals of said two horizontal radiators being arranged opposite to each other in a vertical plane passing through said common axis.

2. A high frequency directive antenna array comprising two stacked antenna systems each having a horizontal radiator including a plurality of conductors arranged horizontally with a common vertical axis, connected together at their ends and forming each a peripherally incomplete loop, one of said conductors being open at its mid point to provide a pair of terminals, said horizontal radiator having an effective electrical length substantially equal to one-half wavelength at said high frequency, a first transmission line connected to said terminals for transfer of high frequency energy between said horizontal radiator and said first line; each of said two antenna systems further having a vertical radiator including a coaxial member having a cylindrical conductor and a center conductor extending beyond said cylindrical conductor, a further outer conductor surrounding said cylindrical conductor, said outer conductor being connected to the free end of said cylindrical conductor, said vertical radiator being arranged vertically along said common axis and having an effective electrical length substantially equal to one-half said wavelength, and a second transmission line connected to said coaxial member for transfer of high frequency energy between said vertical radiator and said second line, the terminals of said two horizontal radiators being arranged opposite to each other in a vertical plane passing through said common axis.

3. A high frequency directive antenna array comprising two stacked antenna systems each having a horizontal radiator including a plurality of closely spaced conductors arranged horizontally with a common vertical axis, connected together at their ends and forming each a peripherally incomplete loop, one of said conductors being open at its mid point to provide a pair of terminals, said horizontal radiator having an effective electrical length substantially equal to one-half wavelength at said high frequency and being so proportioned that its horizontal field strength pattern approaches a circle, a first transmission line connected to said terminals for transfer of high frequency energy between said horizontal radiator and said first line; each of said two antenna systems further having a vertical radiator including a coaxial member having a cylindrical conductor and a center conductor extending beyond said cylindrical conductor, a further outer conductor surrounding said cylindrical conductor, said outer conductor being connected to the free end of said cylindrical conductor, said vertical radiator being arranged vertically along said common axis and having an effective electrical length substantially equal to one-half said wavelength, and a second coaxial transmission line connected to said coaxial member for transfer of high frequency energy between said vertical radiator and said second line having a difference in phase of susbtantially 90 degrees in time with respect to the phase of said high frequency energy transferred between its associated horizontal radiator and said first line, the terminals of said two horizontal radiators being arranged opposite to each other in a vertical plane passing through said common axis.

4. A high frequency directive antenna array for radiating circularly polarized waves substantially uniformly in all horizontal directions comprising a source of high frequency energy, a plurality of stacked antenna systems each having a horizontal radiator including a plurality of conductors arranged horizontally with a common vertical axis, connected together at their ends and forming each a peripherally incomplete loop, one of said conductors being open at its mid point to provide a pair of terminals, said horizontal radiator having an effective electrical length substantially equal to one-half wavelength at said high frequency, a first transmission line connected to said terminals for transferring high frequency energy from said source to said horizontal radiator; each of said antenna systems further having a vertical radiator including a dipole conductor arranged vertically along said common axis, said vertical radiator having an effective electrical length substantially equal to one-half said wavelength, a second transmission line connected to said vertical radiator for transferring high frequency energy from said source to said vertical radiator, the terminals of said horizontal radiators being arranged symmetrically about said common axis and in a vertical plane passing through said common axis, and phase shifting means arranged between said radiators and said source for energizing said array so that the phase of the energy radiated from each of said horizontal radiators is equal, while the energy radiated from each of said vertical radiators is displaced in phase by substantially 90 degrees in

time against the phase of the energy radiated from said horizontal radiators.

5. A high frequency directive antenna array for radiating circularly polarized waves substantially uniformly in all horizontal directions comprising a source of high frequency energy, two stacked antenna systems each having a horizontal radiator including a plurality of closely spaced conductors arranged horizontally with a common vertical axis, connected at their ends and forming each a peripherally incomplete loop, said horizontal radiator having an effective electrical length substantially equal to one-half wavelength at said high frequency, a shielded parallel wire line for transferring high frequency energy from said source to said horizontal radiator and electrically coupled to one of said conductors at its mid point; each of said two antenna systems further having a vertical radiator including a coaxial member having a cylindrical conductor and a center conductor extending beyond said cylindrical conductor, a further outer conductor surrounding said cylindrical conductor, said outer conductor being connected to the free end of said cylindrical conductor, said vertical radiator being arranged vertically along said common axis, a coaxial transmission line connected to said coaxial member, phase shifting means for connecting said source to said coaxial transmission line for transferring high frequency energy between said source and said vertical radiator having a difference in phase of substantially 90 degrees in time with respect to the phase of said high frequency energy transferred to its associated horizontal radiator, the mid points of the conductors connected to said parallel wire lines being arranged opposite to each other in a vertical plane passing through said common axis.

PAUL J. KIBLER.

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