

April 26, 1966

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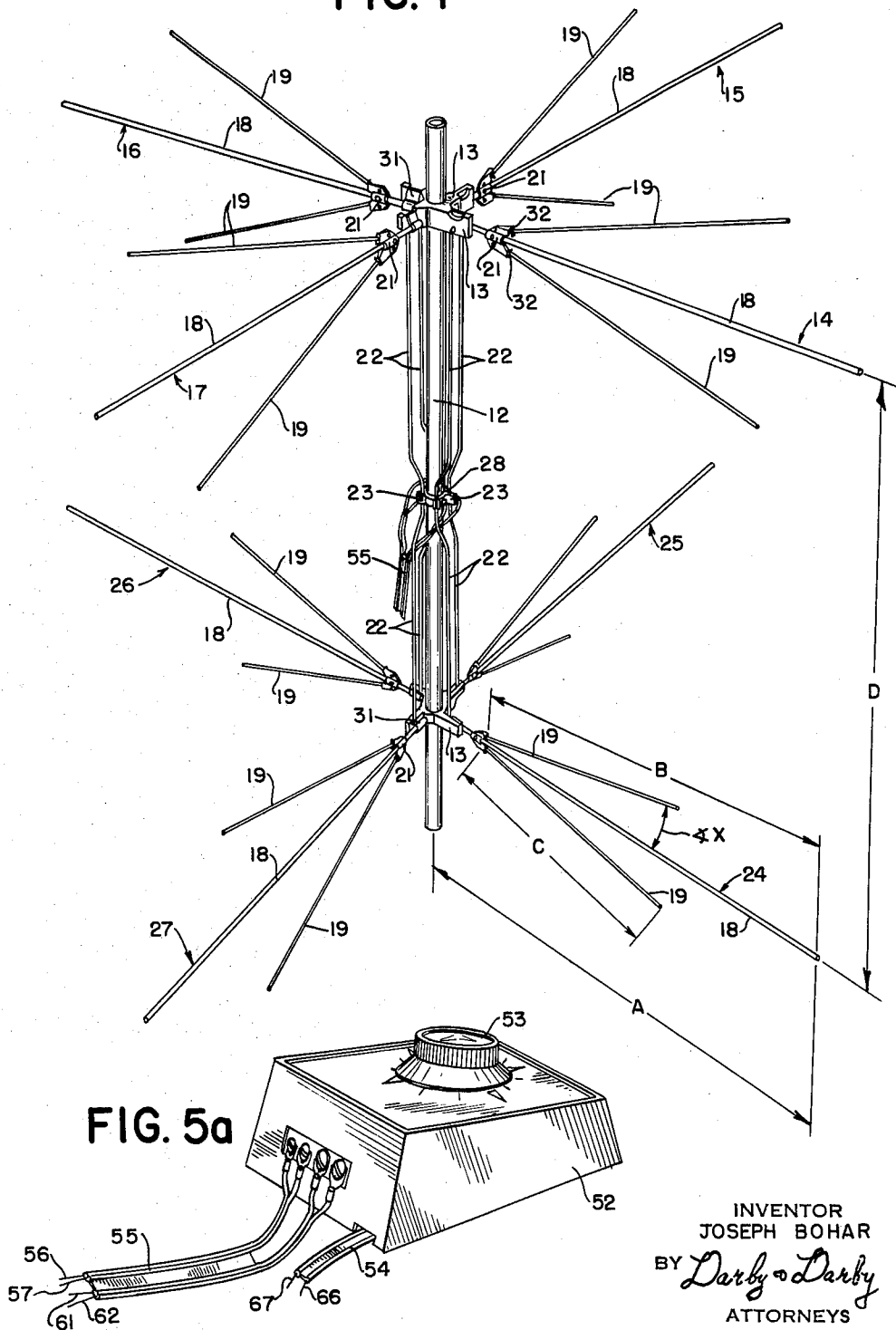
3,248,736

ELECTRICALLY DIRECTABLE MULTI-BAND ANTENNA

Filed Oct. 16, 1962

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FIG. 1



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FIG. 2

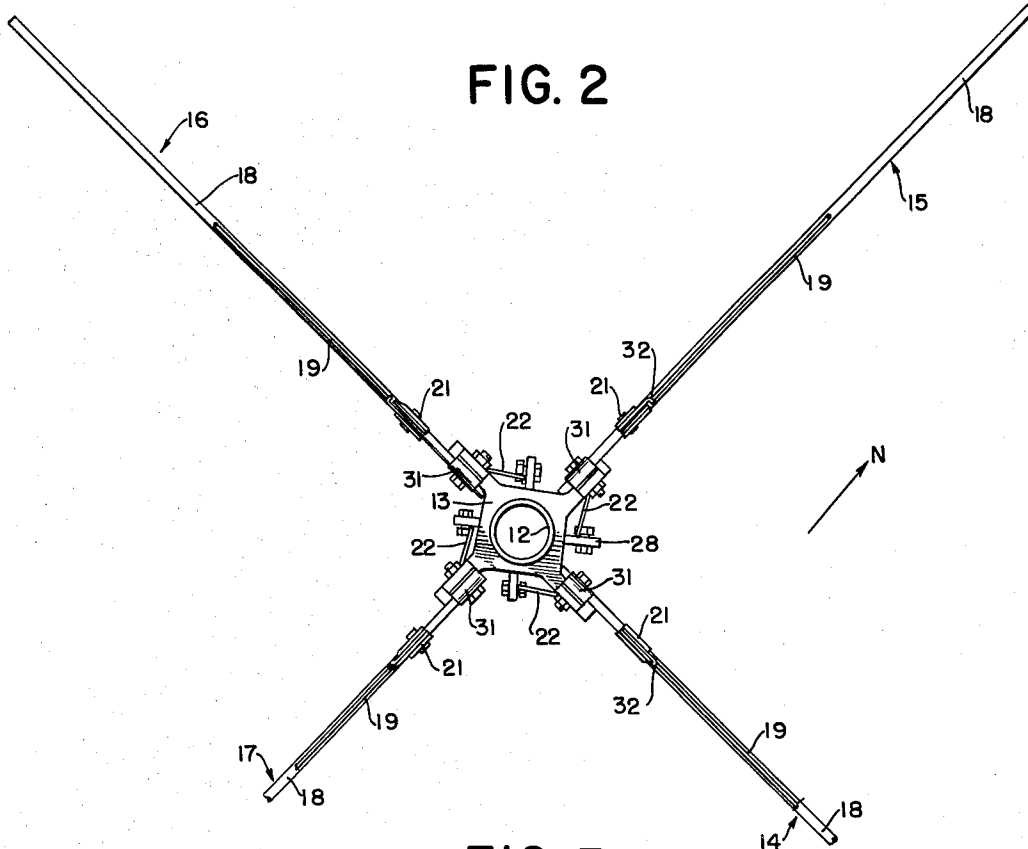


FIG. 3

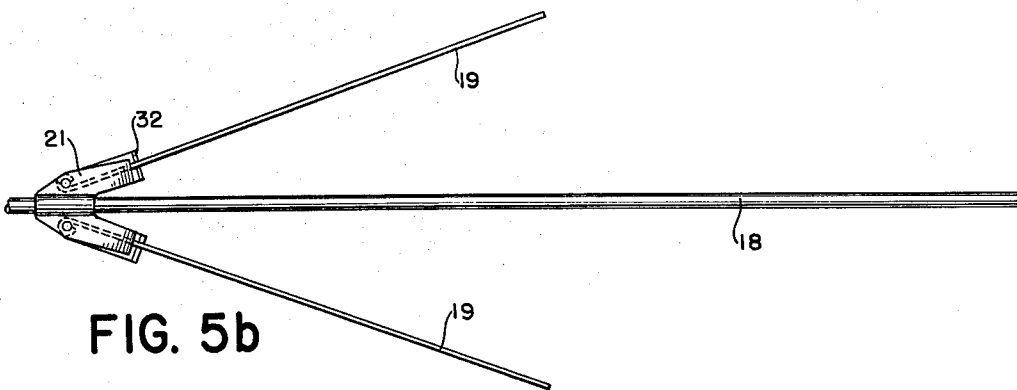
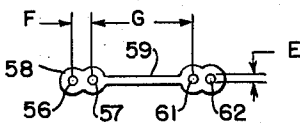


FIG. 5b



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FIG. 7

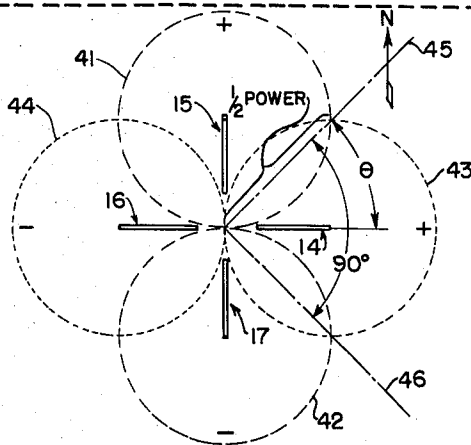
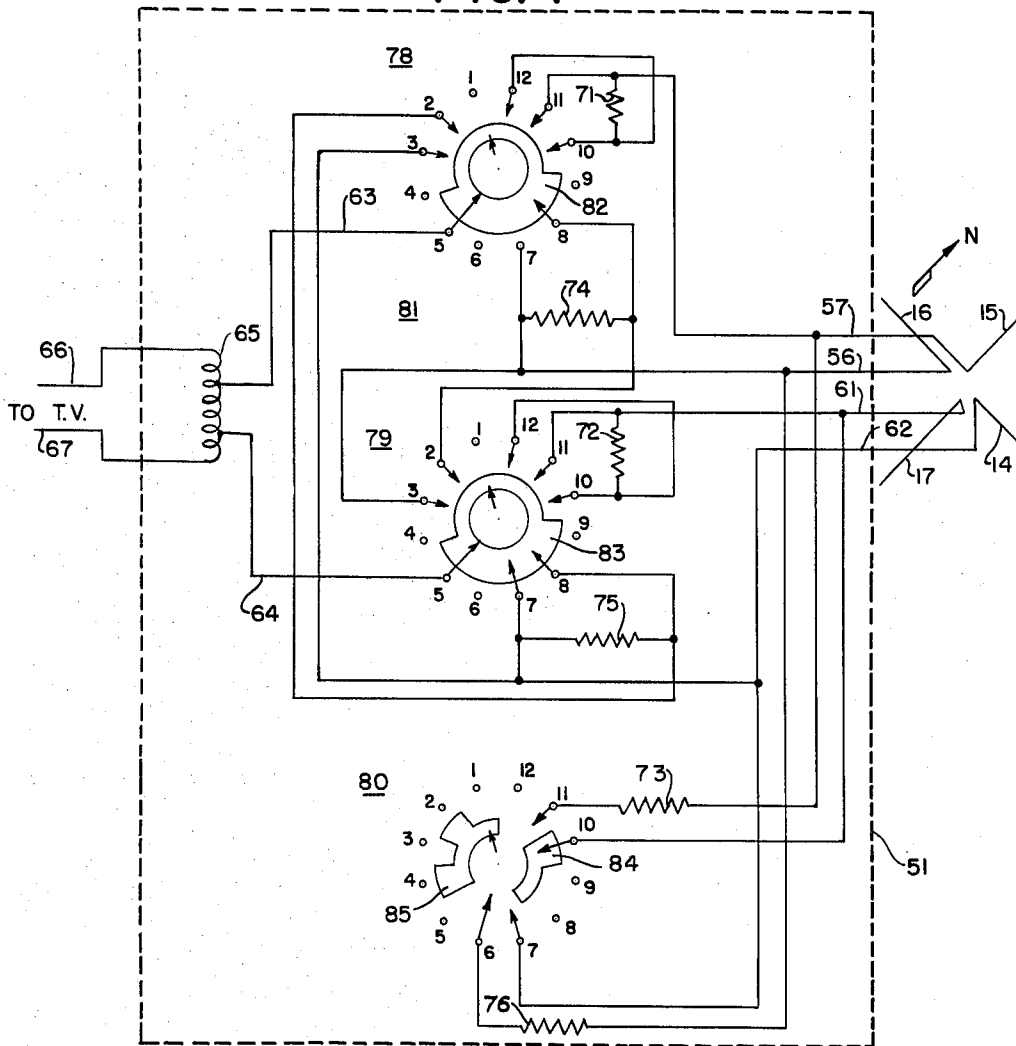


FIG. 4

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FIG. 6a

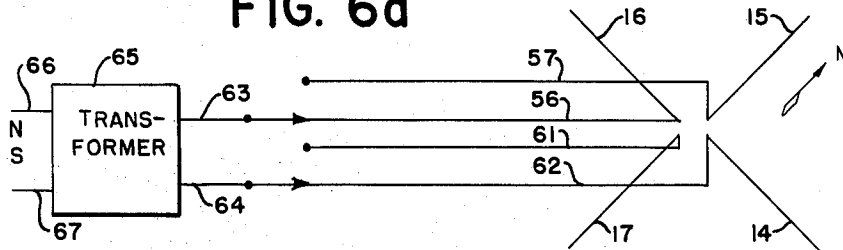


FIG. 6b

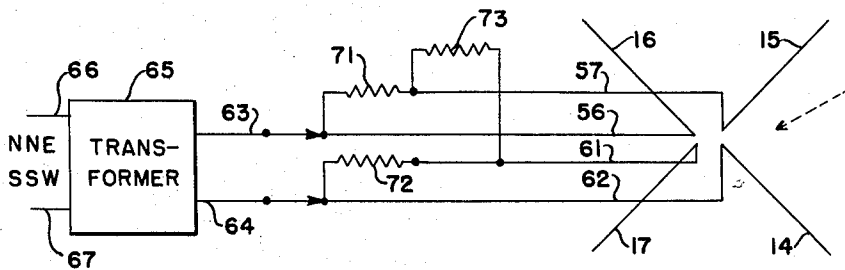


FIG. 6c

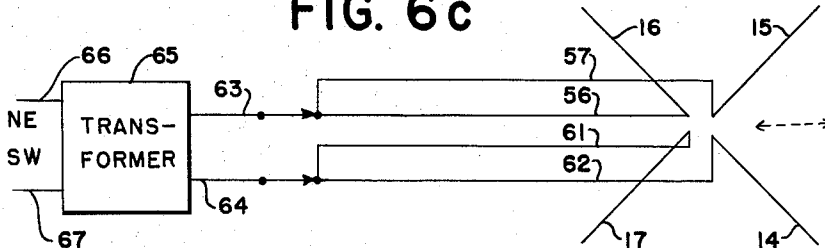
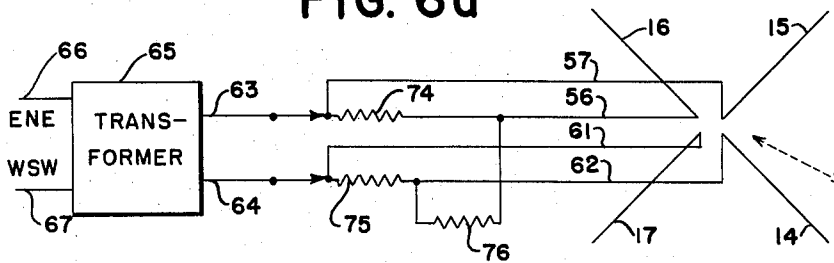


FIG. 6d



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FIG. 6e

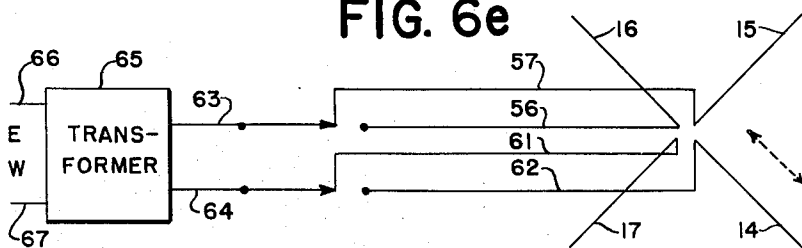


FIG. 6f

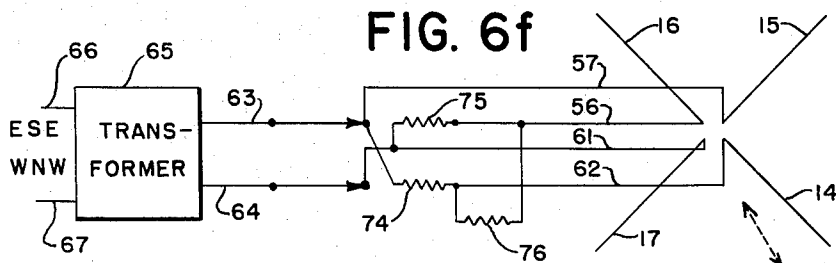


FIG. 6g

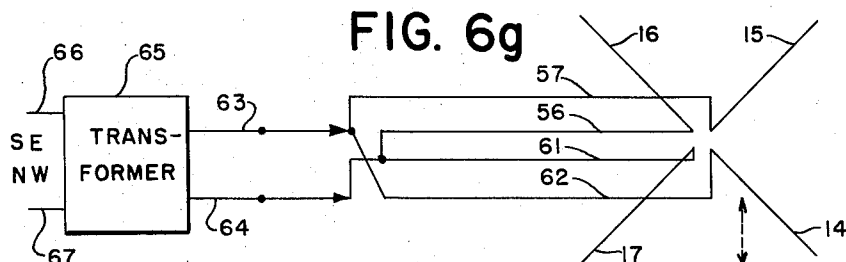
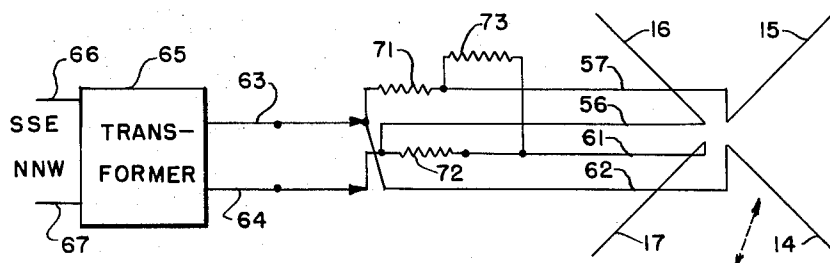


FIG. 6h



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3,248,736 ELECTRICALLY DIRECTABLE MULTI-BAND ANTENNA

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4 Claims. (Cl. 343-797)

The present invention relates to antennas, and particularly television receiver antennas, mountable at a substantial distance from the television receiver and which have various directivity patterns which are selectable by means of a switching unit located near the television receiver. More particularly the invention relates to such antennas which are designed to be effective at operating frequencies throughout the high and the low VHF television bands.

It is frequently desirable, particularly for the reception of television or frequency-modulated radio signals, to provide a directional receiving antenna which is directable to receive from a selected direction with good receptivity and to discriminate against signals from other directions.

This may be accomplished by arranging a directional antenna on a mast with a motor connected to rotate the antenna in azimuth. Such arrangements are heavy and expensive and require complicated equipment at the receiver to control the motor and to indicate in which direction the antenna is oriented.

Another solution to this problem has been to have in effect two different antennas oriented in different directions, for example at 90° to each other. Separate down leads are provided for the antennas and connection of one or the other antennas to a receiver by appropriate switching will provide reception from a selected one of two different directions spaced in azimuth by 90°. It has also been known to provide more complicated switching whereby the multiple antennas are connected to provide intermediate directions of receptivity. Antennas of the foregoing type will be referred to as electrically directable antennas.

One or more difficulties have generally been encountered with such antennas that have limited their usefulness. For example, such antennas have generally provided limited gain especially where they were required to cover a wide range of frequencies such as the high band (174-216 mc.) and low band (54-88 mc.) portions of the VHF television band. Furthermore optimizing the directivity characteristics of antennas of this type on one of the VHF television bands tended to diminish the effectiveness of the antenna on the other VHF band.

Another difficulty encountered with such antennas has been unwanted coupling between the multiple down leads from the various antenna elements. The present invention provides a very simple improved antenna down lead or transmission line which simply and effectively minimizes unwanted intercoupling.

A further difficulty encountered with respect to electrically directable antennas has been the difficulty in obtaining a sufficient number of distinct radiation patterns to obtain the desired degree of directional selectivity. By the present invention eight distinct directivity patterns which provide quite adequate directional selectivity are obtained in a simple and effective manner.

In addition to providing the above described features and advantages it is an object of the present invention to provide an electrically directable antenna adapted for use over a wide range of frequencies including the high and low VHF television bands which bear a frequency ratio of greater than two to one.

It is another object of the present invention to provide such an antenna having dual band dipole elements com-

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prising central rods and whisks extending from the central rods from a point less than a quarter of the distance from the central termination of said rods to the outer ends thereof.

It is another object of the present invention to provide a transmission line for an electrically directable antenna which unites in a single physical structure at least two pairs of conductors arranged to minimize unwanted signal coupling between certain pairs of the conductors.

It is still another object of the present invention to provide an electrically directable antenna system having a switching circuit to be located at a receiver which is simple and effective and provides as many as eight distinct radiation patterns.

It is a still further object of the present invention to provide an antenna system of the foregoing type in which each of the antenna radiation patterns is in itself bidirectional.

Other objects and advantages will be apparent from a consideration of the following description in conjunction with the appended drawings in which:

FIGURE 1 is a perspective view of an antenna according to the present invention;

FIGURE 2 is a plan view of the antenna of FIGURE 1;

FIGURE 3 is an enlarged detail elevational view of one arm of the antenna of FIGURE 1;

FIGURE 4 is an illustrative radiation pattern presented to aid in the explanation of the operation of the antenna according to the present invention;

FIGURE 5A is a plan view of the receiver-located switching box and of the transmission line forming parts of the electrically directable antenna system according to the present invention;

FIGURE 5B is a cross sectional view of the transmission line of FIG. 5A.

FIGURES 6A through 6H are diagrams, partially schematic in form, showing the electrical connections provided to create various radiation patterns for the antenna according to the present invention; and

FIGURE 7 is a schematic circuit diagram of the receiver-located switch mechanism forming a part of the antenna system according to the present invention.

Referring now to FIGURE 1, an antenna 11 is shown with a supporting mast 12 which is vertically supported in any suitable manner, not shown. Insulating mounting blocks 13 are provided in order that antenna dipole arms 14, 15, 16 and 17 and 24, 25, 26 and 27 may be horizontally supported from mast 12 while at the same time being substantially electrically insulated from mast 12 and from each other.

Each of the dipole arms 14-17 and 24-27 comprises a dipole rod 18 and two conductive whisks 19 secured near the inner end of the dipole rod 18 by means of a mounting fixture 21.

Whiskers 19 are preferably two in number for each dipole arm and disposed above and below the dipole rod 18 in a substantially vertical plane including rod 18. Whiskers 19 are arranged at an acute angle with respect to the outboard portion of dipole rod 18, and are secured by means of fixture 21 near the inboard ends of dipole rod 18.

Any two of the dipole arms 14-17 will form a dipole antenna of either the straight type or the V-type depending on whether the arms are opposite arms or adjacent arms. The same is true of dipole arms 24-27. If corresponding arms of the set of dipole arms 24-27 are suitably connected to their matching arms of the set of dipole arms 14-17 then a vertically stacked antenna array is provided having approximately twice the gain of either of the single antennas. The vertical spacing of dipoles will depend on numerous factors but may generally be

about one-quarter wavelength on the low VHF television band.

Corresponding ones of the sets of dipole arms 14-17 and 24-27 are connected by conductors 22 which are also provided with terminals 23 midway between the upper and lower set of arms. An insulating block 28 is provided to isolate terminals 23 electrically from mast 12 and from each other.

A down lead or transmission line 55 is provided having four conductors each of which is connected through a respective stacking conductor 22 to one of the vertically disposed pairs of dipole arms as, that is, (14, 24), (15, 25), (16, 26) and (17, 27).

The structure and function of the down lead or transmission line 55 will be explained in detail hereinafter, and it will suffice for the present to say that transmission line 55 provides in a simple and inexpensive manner the required isolation between conductors leading to the various antenna arms which makes possible proper remote control of the antenna radiation pattern.

It may be noted, particularly in FIGURES 1 and 3, that antenna rods 18 and whisks 19 may desirably be collapsibly mounted with respect to mast 12 and provided with spring catches 31 and 32 respectively to provide rapid erection of the antenna. It should be noted that many of the advantages of the present antenna system are achievable without the necessity for a stacked array as described and illustrated herein. For example an antenna comprising only dipole arms 14-17 and omitting dipole arms 24-27 would be useful and have many advantages of the present system but would provide lower gain than the stacked array illustrated and described.

This being the case, the description of the operation of the antenna will in some cases be referred to that portion comprising dipole arms 14-17 alone, it being understood that arms 24-27 will operate in a similar fashion and in concert with arms 14-17 to increase the gain of the antenna array.

Referring now to FIGURE 4, dipole arms 14, 15, 16 and 17 of the antenna are illustrated as seen from above. Consider that arms 14-17 form a pair of dipole antennas with arms 14 and 16 forming a first dipole antenna and arms 15 and 17 forming another dipole antenna oriented at 90° to the first. At the antenna operating frequency for which each of the dipole arms is approximately one-quarter wavelength long, each of the pair of dipoles 14, 16 and 15, 17 will comprise a half-wave dipole antenna and will have a fairly broad bidirectional radiation pattern.

For example the radiation pattern of dipole 14, 16 may be represented approximately as indicated by dashed lines 41 and 42 while the radiation pattern of dipole 15, 17 may be approximately represented by dotted lines 43 and 44. It may be noted that each of the dipoles 14, 16 and 15, 17 is on the axis of the other dipole and consequently will have little effect on the radiation pattern of the other dipole so long as it is not coupled to the apparatus for which the antenna is used. It should be noted that while the antenna system of the present invention is designed for use with home television receivers, such antenna systems are not limited to this use and are of general utility as multi-band or wide-band receiving or transmitting antennas. As is well known, reciprocity exists with respect to characteristics of transmission and reception for antennas.

For convenience the lobes 41, 42, 43 and 44 will be described as north, south, east, and west. From FIGURE 4 it will be apparent that connecting only dipoles 14 and 16 to the receiver will provide a north-south bidirectional radiation receptivity pattern. It will also be apparent that connecting only dipole arms 15 and 17 to the receiver will provide an east-west bidirectional radiation receptivity pattern.

It is also intuitively apparent from FIGURE 4 that

connecting only dipole arms 14 and 15 to the receiver would provide a V-dipole antenna with northeast and southwest radiation pattern lobes and with somewhat better reception in the northeast direction. While directivity could be obtained in such a manner it is preferred to obtain directivity of this type by connecting all four dipole arms to the receiver with arms 14 and 17 connected to one terminal of the receiver and arms 15 and 16 connected to the other terminal of the receiver. A bidirectional northeast-southwest pattern is thereby obtained.

In analyzing this mode of operation of the antenna it is useful to consider that dipoles 15, 17 and 14, 16 are concurrently in operation. It should further be noted that the backward and forward lobe of a dipole antenna of one-half wavelength have opposite phases. This is indicated by the plus and minus signs in FIGURE 4. It will be noted that radiation lobes 41 and 43 are both shown as positive and may be considered to reinforce and also that radiation lobes 42 and 44 are both negative and may be considered to reinforce. On the other hand lobes 42 and 43 or 41 and 44 interfere. That is lobes of opposite sign in FIG. 4 tend to have a subtractive effect.

With this background it is appropriate to describe an important aspect of the antenna according to the present invention which has not heretofore been explained. With the usual directional antenna it is desired to obtain a narrow lobe radiation pattern since this pattern generally provides a higher gain and preferred direction. However in the present antenna system, unexpectedly, it is found that superior performance is provided if the dipole antennas have a radiation pattern with a half power angular width of approximately 90° or at least greater than 75°. This situation may be understood if one considers FIGURE 4 and the operation of the antenna in the northeast-southwest receptivity mode.

It is convenient and reasonably accurate to analyze the operation of the antenna in the northeast-southwest receptivity mode by considering that the antenna is operating with two dipoles formed of arms 14 and 16 and of arms 15 and 17 respectively in concurrent operation.

It should be noted that in such a case the effect of lobes 41 and 43 are substantially additive (as are the effect of lobes 44 and 42). Assuming that lobes 41 and 43 are similar they will have points of equal receptivity along a line 45 bi-secting the angle between arms 14 and 15 and thus at an angle of 45° with respect to each of these arms. If lobes 41 and 43 are so narrow that the receptivity along line 45 is low, the total receptivity in the northeast-northwest mode will be poor in a northeasterly direction. As a rule of thumb, the receptivity in terms of power at line 45 should not be much less than one-half of the maximum for lobes 41 and 43. In such a case the combined receptivity of the two lobes in the exact northeasterly direction would be not materially less and preferably as good as lobe 41 alone when the antenna is in the north-south mode of operation or for lobe 43 alone when the antenna is in the east-west mode of operation.

Thus it will be seen that the total angular width of the radiation pattern for a pair of collinear dipole arms should be approximately 90° as indicated in FIGURE 4. As will later be seen the present invention provides substantially such conditions not only at one particular frequency but over a broad range of frequencies in both the high and low VHF television bands. A 45° off-axis receptivity of slightly greater than one-half power would be acceptable, but the actual obtainable 45° off axis receptivity over a wide range of frequencies is, according to the invention, generally slightly less than one-half of the maximum receptivity.

It will be noted that the radiation lobes in FIG. 4 are shown as circular. This is of course an ideal condition obtainable in practice to a reasonable degree of approximations. FIG. 4 represents the radiation pattern not in terms of power but in terms of field strength ac-

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cording to usual practice. The power is proportional to the square of field strength which explains the fact that the radial coordinates of the radiation lobes at 450° off axis are .707 or $\sqrt{1/2}$. The half-power beam width is thus 90°.

It should also be noted that it is desirable to approach the circular shape of the radiation patterns of FIG. 4 in order to provide proper reception in different directions. This arises from the fact that the summation of two circular patterns angularly displaced by 90° is another circular pattern located at an angle midway between the two. This will be understood by considering the polar coordinate equations of lobes 41 and 43 in FIG. 4 (taken East as $\theta=0$).

$$\begin{aligned} R_{41} &= \sin \theta \\ R_{43} &= \sin (\theta + 90^\circ) \\ R_{41} + R_{43} &= \sin \theta + \sin (\theta + 90^\circ) \\ &= 2 \sin \frac{1}{2} (2\theta + 90^\circ) \cdot \cos \frac{1}{2} (-90^\circ) \\ &= \sqrt{2} \sin (\theta + 45^\circ) \end{aligned}$$

Thus the summation of lobes 41 and 43 produces a circular lobe with a maximum midway of lobes 41 and 43 (there being an identical lobe in the opposite quadrant as well). The above analysis is intentionally greatly simplified and ignores phase relations etc., but is believed useful to point out the desirable advantages obtained by a half-power beam width of about 90° and approximately circular field radiation lobes.

A suitable broad radiation pattern is maintained throughout the antenna design frequency range by the novel dipole structure according to the invention, an example of which is illustrated in FIGURES 1 through 3. It may first be noted that additional gain is obtained by vertically stacking the antenna. In this way additional gain is obtained by shaping the radiation pattern in the vertical plane but there is substantially no narrowing of the radiation pattern in the horizontal plane by virtue of the stacking. In the embodiment illustrated the two antennas stacked to form an array have the exact same orientation, but if desired, the upper and lower dipole sets could be angularly displaced by a small angle which would tend to broaden the composite antenna horizontal radiation pattern. The angular displacement could for example be 10°-15°.

Whiskers of superficially similar appearance to whiskers 19 have previously been employed to improve antenna reception, in the high band portion of the VHF television band for example. In such cases it has generally been the purpose to obtain a properly directed narrow radiation pattern and the enhanced gain which generally follows from such a narrow pattern. On the other hand the present invention seeks to avoid narrowing the beam radiation pattern. The whiskers 19 employed in the present antenna combination will be noted to join the antenna dipole rod 18 at a point substantially removed from the inboard end of the rod 18 but substantially inboard of the midpoint of dipole rod 18. This novel placement of the whiskers 19 obtains a result which has heretofore not been appreciated nor obtained, namely providing a relatively broad radiation pattern over the high and low band of the VHF television frequency allocation.

The operation of the individual dipole antennas on the low band is only slightly modified by whiskers 19 since they are of a relatively short length compared to a quarter wavelength at the low band frequencies. The whiskers 19 do however provide a desirable effect on the low VHF television band in that they tend to make the dipole arm fatter and hence give it a broadband characteristic. The whiskers 19 also allow the dipole rods 18 to be made longer (than one quarter wavelength) without deteriorating the operation at the high end of the low VHF television band. The longer dipole rod 18 than would be necessary without whiskers 19 enhances the performance of the dipole antenna throughout the low frequency band.

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On the high frequency band whiskers 19 form a major radiating element of the antenna since they are, at those frequencies, approximately one quarter-wave length. Placing the junction of whiskers 19 at a point spaced from the inboard end of dipole rod 18 provides greatly improved performance over that obtained if the whiskers 19 were simply connected, in parallel as it were, at the inboard end of dipole rod 18.

The novel placement of whiskers 19 is believed to render the portion of the dipole rod outboard of the fixture 21 of such length to minimize adverse interaction from this electrically long conductor rod on the high band portion of the VHF television band.

It will be understood that while the foregoing explanation of the operation of the antenna and the further explanation hereinafter to be presented are believed to be correct, the operability and advantages of the antenna are not predicated upon the particular explanation of operation presented but are rather based on the actual operation of the antenna combination.

Referring now to FIGURES 5A and 5B a directional control switching unit 51 is shown comprising a housing 52 having rotatably mounted thereon a selector knob 53.

The selector knob 53 controls a rotary switch, the details of which will be described hereinafter. The control unit 51 is provided with a conventional antenna lead 54 for connection to the television receiver. In a typical case the transmission line 54 will be a two-wire transmission line with a 300 ohm characteristic impedance. In any case, the transmission line 54 may be adapted to provide a matching connection to the television receiver.

A novel form of four-wire transmission line 55 is provided for connecting a control unit 51 to the antenna of FIGURES 1, 2 and 3. The electrical characteristics of the four-wire transmission line 55 are of course subject to variation within the skill of the art, but for purposes of explanation a particular form of such line will be described. The transmission line 55 described, has a first pair of conductors 56, 57 which are relatively closely spaced to form a two-wire transmission line with a characteristic impedance of approximately 150 ohms. The four-wire transmission line 55 is provided with an insulating jacket 58 which prevents the conductors 56 and 57 from making electrical contact with the antenna mast or other metal objects between the control unit 51 and the antenna 11. The insulating jacket 58 also serves to maintain the desired separation between the various conductors.

The four-wire line transmission line 55 includes a second pair of conductors 61, 62 which are spaced from each other in a manner similar to the previously described conductors 56, 57. The pair of conductors 61, 62 is however, spaced by a relatively large distance from the pair of conductors 56, 57 which spacing is maintained by a web 59 forming a part of the transmission line jacket 58. Substantial isolation is obtained between the conductor pairs if the distance between median lines of the respective pairs is at least four times, and preferably about six times, the spacing between the conductors of each pair.

The spacing provided by web 59 causes an isolation of approximately 15 db or greater between the transmission line comprising conductors 56, 57 and the transmission line comprising conductors 61, 62 in a typical antenna installation. It should be noted in this regard that the control unit 51 has an impedance when viewed from the terminals connected to four-wire transmission line 55 which is matched to the impedance (for example 150 ohms) of transmission line 56, 57 or of transmission line 61, 62. This impedance characteristic of the control unit 51 is desirable to prevent reflections or loss of signal from the antenna and it also serves to maintain the isolation between transmission line 56, 57 and transmission line 61, 62.

It should be noted that in previous forms of four-wire

transmission line for television antennas or the like it was generally the practice to provide a balanced line by arranging each of the four conductors at the corners of a square or to form a semi-balanced line by arranging four conductors equally spaced in a straight line. On the other hand, the present invention obtains desirable advantages by an intentionally irregular four-wire transmission line.

Transmission line 56, 57 is connected to two collinear dipole arms of the antenna, for example, arms 14 and 16 while transmission line 61, 62 is connected to the other collinear set of dipole arms 15 and 17. The connection is of course made through terminals 23 and stacking conductors 22 in the case of the stacked antenna illustrated in FIGURES 1-3.

As will later be seen from the details of the antenna switching circuit, there is never a case in which one and not the other of the conductors 61 and 62 is being utilized. That is, either both conductors are being utilized or neither of the conductors is being utilized of this particular pair. This being the case, relatively little separation is required as provided by web 59 from the other pair of conductors 56, 57 to provide a high degree of isolation and substantially prevent coupling between transmission line 61, 62 and transmission line 56, 57. The previously described condition also exists for the pair of conductors 56, 57 that is, either they are both being utilized at a given time or neither of them is being utilized at a given time.

It can be readily appreciated that an elimination of intercoupling in the down lead or transmission line 55 is important to proper operation of the electrically directable antenna. This can be appreciated if one considers the case where substantial coupling existed between transmission line 56, 57 and transmission line 61, 62. It would then be impossible to provide a connection for reception from only one collinear set of dipoles, for examples, 14, 16, to obtain selective reception from the north-south directions.

The dimensions and parameters for the antenna and transmission line thus far described will be determined by the desired operating characteristics such as frequency, impedance, etc., as will be apparent to one skilled in the art. However, to aid in practice of the invention an example of dimensions etc. is given below in Table I for an antenna for a television receiver to cover the VHF television band extending from 54-88 and from 174-216 mc.

Table I

Reference letter from	Dimension
FIG. 1, 2, 3 or 5B	
A -----	in-- 46
B -----	in-- 41
C -----	in-- 16 3/4
D -----	in-- 40 1/2
E -----	Approx. in-- .03
F -----	Approx. in-- 5/64
G -----	Approx. in-- 25/64
X -----	degrees-- 20

Referring now to FIGURES 6A through 6H, the manner in which eight different modes of reception are provided, will be described. FIGURES 6A through 6H illustrate schematically the antenna of FIGURES 1 through 3 with dipole arms 14, 15, 16 and 17 having connected thereto conductors 62, 57, 56 and 61 respectively of the four-wire transmission line 55.

The switching mechanism in control unit 51 causes two or four of the arms 14 through 17 to be connected to the leads 63, 64 of a balun transformer 65. The secondary of the balun transformer 65 is also connected to the receiver through leads 66, 67 of transmission line 54. The balun transformer 65 may be of conventional type and is utilized as may be necessary to transform from the characteristic impedance required for proper connection

to the receiver terminals, usually 300 ohms, to the characteristic impedance of the four-wire transmission line 55, which for illustrative purposes will be considered to be 150 ohms in the present explanation.

Referring now to FIGURE 6A, it will be noted that leads 63 and 64 from balun 65 are connected respectively to arms 16 and 14 of the antenna. This provides a simple dipole antenna having a north-south directivity.

Before referring to FIGURE 6B it will be useful first to consider FIGURE 6C. In FIGURE 6C it will be noted that balun leads 63 and 64 are connected to all four dipole arms with balun leads 63 connected to arms 15 and 16 and with balun leads 64 connected to arms 14 and 17. As was explained with reference to FIGURE 4, such a connection may be considered to cause collinear dipole arms 15 and 17 to operate in conjunction with collinear dipole arms 14 and 16 to provide a receptivity pattern which is approximately equivalent to the summation of the respective patterns of the two sets of collinear dipoles 14, 16 and 15, 17. One may also consider that in the arrangement of FIGURE 6C there are two back to back V-dipole antennas facing respectively in the northeast and southwest direction. Whatever the method of analysis of the circuit, it will be apparent that the connection of FIGURE 6C provides northeast-southwest directivity.

Referring now to FIGURE 6B, it will be noted that all four dipole arms are connected to balun 65 as in the case of FIGURE 6C but that for certain of the arms an attenuation is produced by a series-parallel resistance network. The attenuating network comprises series resistors 71 and 72 and parallel resistor 73. The amount of attenuation which should be provided by the network comprising resistor 71, 72 and 73 is not particularly critical but approximately 6 db attenuation of power is satisfactory. The attenuator network is, of course, matched to the impedance of the transmission line. Values of 75 ohms for resistors 71 and 72 and 300 ohms for resistors 73 provide satisfactory operation.

The circuit arrangement illustrated in FIGURE 6B is the same as that of FIGURE 6C except for the attenuation imparted with respect to the signal from the dipole 15-17. This attenuation causes the directivity to shift slightly to favor the direction of directivity of dipole arms 14 and 16 which are not attenuated. That is, the directivity is shifted slightly to the north.

It should be pointed out that in some cases the utility of the circuit arrangement of FIGURE 6B will reside in the shifting of the direction of the null receptivity point for the antenna rather than in any shifting of the maximum receptivity point. For example, interference from an unwanted signal may be eliminated by adjusting the antenna null for discrimination against the unwanted signal.

The operation of circuits 6B and 6C is believed obvious from a consideration of these figures and of FIGURE 4. Referring to FIGURE 4 note that the circuit arrangement of FIGURE 6C would cause receptivity lobes 41 and 43 to be effectively additive and provide a receptivity maximum in the northeast direction. Similarly lobes 42 and 44 would provide receptivity in the southwest direction. Lobes 41 and 44 are of opposite phase and would substantially cancel in the northwest direction, while the subtractive effect of lobes 42 and 43 would provide a null in the southeast direction.

It will also be obvious from FIGURE 4 that where the circuit is connected as illustrated in FIGURE 6B and the signal from dipole 15, 17 is attenuated, the effect would be to reduce the size of lobes 43 and 44. This would in turn cause a counterclockwise shifting of the maximums and nulls of the radiation pattern for the phase relations indicated by the plus and minus signs in FIGURE 4. If the leads to one dipole were reversed the shift would be clockwise. Ideally, this shift-

ing should be $22\frac{1}{2}^\circ$ to provide an exactly intermediate directivity setting. In practice a shift of anywhere from 15° to 30° would be satisfactory.

From the foregoing explanation, it is believed clear how the circuit arrangements of FIGURES 6A through 6C provide electrically controllable directivity in steps of approximately $22\frac{1}{2}^\circ$. FIGURES 6D through 6H may be related to the previously explained FIGURES 6A through 6C. For example, FIGURE 6D illustrates a connection which is similar to FIGURE 6C except that dipole 14-16 is attenuated rather than dipole 15-17. As a result, the pattern of FIGURE 6C is shifted somewhat toward the east to provide an east by northeast-west by southwest directivity.

FIGURE 6E shows the connection of dipole antenna 15-17 alone to provide east-west directivity. FIGURE 6F is similar to FIGURE 6D except that the dipole 14-16 and the dipole 15-17 have opposite relative polarities as compared with FIGURE 6D. The resulting directivity of FIGURE 6F is in the east by southeast-west by northwest direction.

The circuit connection of FIGURE 6G is similar to that of 6C except for the switching of the relative polarities of dipoles 14-16 and 15-17. The directivity of the arrangement of FIGURE 6G is in the southeast-northwest direction.

The circuit arrangement of FIGURE 6H is similar to that of FIGURE 6B previously explained except for switched polarity of dipoles 14-16 and 15-17 and the directivity provided is south by southeast and north by northwest. From the foregoing explanation it will be seen that the circuit arrangements of FIGURES 6A through 6H provide eight bidirectional directivity patterns spaced at steps of approximately $22\frac{1}{2}^\circ$.

The circuit arrangements of FIGURES 6A through 6H are simply and reliably provided by the rotary switch mechanism in control unit 51 which is illustrated in FIGURE 7. Referring now to FIGURE 7 it should first be pointed out that it may be convenient to have more than eight switch positions although only eight unique directional patterns are provided. For example, 16 positions could be provided so that the physical orientation of the control knob could conform in direction to one of the two directions of directivity of the antenna. The particular switching circuit here illustrated provides 12 positions, including the 8 basic positions corresponding to FIGS. 6A through 6H.

Referring now to FIGURE 7, the control unit circuit is provided with leads 66 and 67 for connection to the receiver antenna terminals.

The balun transformer 65 provides any necessary impedance transformation to match the impedance of the receiver antenna input terminals to the four-wire antenna transmission line. In the present case, it is assumed that the antenna receiver terminals have an impedance of 300 ohms and that the effective impedance of the four-wire transmission line to the antenna is 150 ohms or 75 ohms, depending on whether only two conductors are being utilized or whether both pair of conductors will preferably provide an impedance transformation 65 will preferably provide an impedance transformer which is a compromise between the 150 ohms and the 75 ohms situation. For example, the impedance transformation may be 3 to 1.

Leads 63 and 64 connect the balun transformer 65 to respective decks 78 and 79 of rotary switch 81. Lead 63 connects to contact 5 on deck 78 which has a slider making continuous contact with armature 82 for switch deck 78. Lead 64 is similarly connected to armature 83 of switch deck 79.

Switch desk 80 of rotary switch 81 controls the insertion of a shunt resistor for attenuation purposes as will later be apparent.

Rotary switch is shown in position 1 and an explanation

of the operation for position 1 and for position 2 will be sufficient for an understanding of the circuit. Position 1 corresponds to the connection illustrated in FIGURE 6A. It will be noted that dipole arm 16 is directly connected through contact 7 on deck 78 and contact 5 to lead 63 from balun 65. Dipole arm 14 is similarly connected through contact 7 on deck 79 and contact 5 to lead 64 from balun 65. It will be noted that shunt resistors 73 and 76 are not in circuit in position 1. Accordingly, the position illustrated in FIGURE 7 corresponds to that shown in FIGURE 6A where the antenna is connected with arms 14 and 16 as a simple collinear dipole.

If the rotary switch 81 is now turned to position 2 it will be noted that armature 82 establishes a connection between lead 63 and balun 65 and dipole arm 15 through resistor 71. Other connections in deck 78 remain the same. In a similar fashion, the armature 83 establishes a connection from lead 74 of balun 65 through resistor 72 to dipole arm 17. Armature 84 makes contact between contacts 11 and 10 thus placing resistor 73 in shunt across leads 57 and 61 leading to dipole 15, 17. Resistors 71, 72 and 73 thereby form a series parallel resistance attenuator in the transmission line from dipole 15, 17, while a direct unattenuated connection is made to dipole 14, 16 thus providing the connection illustrated in FIGURE 6B.

Examination of FIGURE 7 will show that positions 1 through 8 of rotary switch 81 provide the connections illustrated in FIGURES 6A through 6H respectively. Four extra positions are provided for convenience in arranging contacts. Position 9 repeats the connections of position 1 and is accordingly in proper sequence. Positions 10 and 11 provide shunt paths between leads 63 and 64; in position 10 the shunt path being through a 300 ohm resistor and in position 11 the shunt path being direct. Position 12 also provides the same connection as position 1. If desired, stops be provided in the switch to render positions 10 through 12 or some portion thereof inaccessible.

From the foregoing explanation, it will be appreciated that the present invention provides an electrically directable antenna system suitable for use on any or all VHF television channels and which is readily and effectively caused to be directive in any one of 8 bidirectional modes separated by approximately $22\frac{1}{2}^\circ$. The system includes as elements an antenna, a transmission line, and a switching unit all with novel features and it will be understood that such elements will have utility in similar or different systems as well as in the combinations disclosed.

In addition to those modifications and variations to the particular embodiments described and suggested herein, numerous other modifications and variations will be apparent to those of skill in the art and it is accordingly desired that the scope of the invention not be limited to the particular embodiments shown or suggested, but that it be determined by reference to the following claims.

What is claimed is:

1. An electrically directable antenna system for the high and low VHF television bands comprising an antenna array having at least four radially disposed horizontal arms with terminals at their inboard ends, a signal transmission line comprising at least four conductors extending longitudinally of said line and a unitary jacket of dielectric material surrounding and mutually insulating said conductors, said conductors being arranged in pairs, the conductors of each pair being untwisted and parallel with respect to each other and spaced by a distance which conforms to the desired characteristic impedance of said line, and the median lines of the respective pairs of conductors being spaced by a distance at least four times as great as the spacing between the two conductors of any of said pairs of conductors, each arm being connected to a conductor of said transmission line, each said arm being substantially co-linear with at least one other of said arms to form a dipole antenna, said arms having means for

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causing the half-power principal beam width of the horizontal radiation pattern of each said dipole antenna to be between approximately 75° and 95° for frequencies in said high and low VHF television bands, and switch means connected to said signal transmission line for connecting at least two selectable ones of the conductors of said line in different manners to the two terminals of apparatus utilizing said antenna system, said switch comprising at least a first, a second, a third, and a fourth antenna terminal connected to respective conductors of said transmission line, two apparatus terminals for connection to utilization apparatus, means for connecting at least two of said antenna terminals to said apparatus terminals in the following alternative relations,

- (a) said first antenna terminal to one apparatus terminal and said third antenna terminal to the other apparatus terminal,
- (b) said second antenna terminal to one apparatus terminal and said fourth antenna terminal, to the other apparatus terminal,
- (c) said first and second antenna terminals to one apparatus terminal and said third and fourth antenna terminals to the other apparatus terminal, or
- (d) said first and fourth antenna terminals to one apparatus terminal and said second and third antenna terminals to the other apparatus terminal.

2. An electrically directable antenna system for the high and low VHF television bands comprising an antenna array having at least four radially disposed horizontal arms with terminals at their inboard ends, a signal transmission line comprising at least four conductors extending longitudinally of said line and a unitary jacket of dielectric material surrounding and mutually insulating said conductors, said conductors being arranged in pairs, the conductors of each pair being untwisted and parallel with respect to each other and spaced by a distance which conforms to the desired characteristic impedance of said line, and the median lines of the respective pairs of conductors being spaced by a distance at least four times as great as the spacing between the two conductors of any of said pairs of conductors, each arm being connected to a conductor of said transmission line, each said arm being oppositely disposed with at least one other of said arms to form a dipole antenna, said arms having means for causing the half-power principal beam width of the horizontal radiation pattern of each said dipole antenna to be between approximately 75° and 95° for frequencies in said high and low VHF television bands, and switch means connected to said signal transmission line for connecting at least two selectable ones of the conductors of said line in different manners to the two terminals of apparatus utilizing said antenna system, said switch comprising at least a first, a second, a third, and a fourth antenna terminal connected to respective conductors of said transmission line, two apparatus terminals for connection to utilization apparatus, means for connecting at least two of said antenna terminals to said apparatus terminals in the following alternative relations.

- (a) said first antenna terminal to one apparatus terminal and said third antenna terminal to the other apparatus terminal,
- (b) said second antenna terminal to one apparatus terminal and said fourth antenna terminal to the other apparatus terminal,
- (c) said first and second antenna terminals to one apparatus terminal and said third and fourth antenna terminals to the other apparatus terminal or
- (d) said first and fourth antenna terminals to one apparatus terminal and said second and third antenna terminals to the other apparatus terminal.

3. An electrically directable antenna system for the high and low VHF television bands comprising an antenna array having at least four radially disposed horizontal arms with terminals at their inboard ends, a signal transmission line comprising at least four conductors ex-

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tending longitudinally of said lines, each arm being connected to a conductor of said transmission line, each said arm being substantially co-linear with at least one other of said arms to form a dipole antenna, said arms having means for causing the half-power principal beam width of the horizontal radiation pattern of each said dipole antenna to be between approximately 75° and 95° for frequencies in said high and low VHF television bands, and switch means connected to said signal transmission line for connecting at least two selectable ones of the conductors of said line in different manners to the two terminals of apparatus utilizing said antenna system, said switch comprising at least a first, a second, a third, and a fourth antenna terminal connected to respective conductors of said transmission line, two apparatus terminals for connection to utilization apparatus, means for connecting at least two of said antenna terminals to said apparatus terminals in the following alternative relations:

- (a) said first antenna terminal to one apparatus terminal and said third antenna terminal to the other apparatus terminal,
- (b) said second antenna terminal to one apparatus terminal and said fourth antenna terminal to the other apparatus terminal,
- (c) said first and second antenna terminals to one apparatus terminal and said third and fourth antenna terminals to the other apparatus terminal or
- (d) said first and fourth antenna terminals to one apparatus terminal and said second and third antenna terminals to the other apparatus terminal.

4. An electrically directable antenna system for the high and low VHF television bands comprising an antenna array having at least four radially disposed horizontal arms with terminals at their inboard ends, a signal transmission line comprising at least four conductors extending longitudinally of said line, each arm being connected to a conductor of said transmission line, each said arm being oppositely disposed with at least one other of said arms to form a dipole antenna, said arms having means for causing the half-power principal beam width of the horizontal radiation pattern of each said dipole antenna to be between approximately 75° and 95° for frequencies in said high and low VHF television bands, and switch means connected to said signal transmission line for connecting at least two selectable ones of the conductors of said line in different manners to the two terminals of apparatus utilizing said antenna system, said switch comprising at least a first, a second, a third, and a fourth antenna terminal connected to respective conductors of said transmission line, two apparatus terminals for connection to utilization apparatus, means for connecting at least two of said antenna terminals to said apparatus terminals in the following alternative relations:

- (a) said first antenna terminal to one apparatus terminal and said third antenna terminal to the other apparatus terminal,
- (b) said second antenna terminal to one apparatus terminal and said fourth antenna terminal to the other apparatus terminal,
- (c) said first and second antenna terminals to one apparatus terminal and said third and fourth antenna terminals to the other apparatus terminal,
- (d) said first and fourth antenna terminals to one apparatus terminal and said second and third antenna terminals to the other apparatus terminal.

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