Nov. 18, 1952 J. E. PAUCH 2,618,746

ANTENNA SYSTEM

Filed Aug. 13, 1948 3 Sheets-Sheet 1

Fig. 1

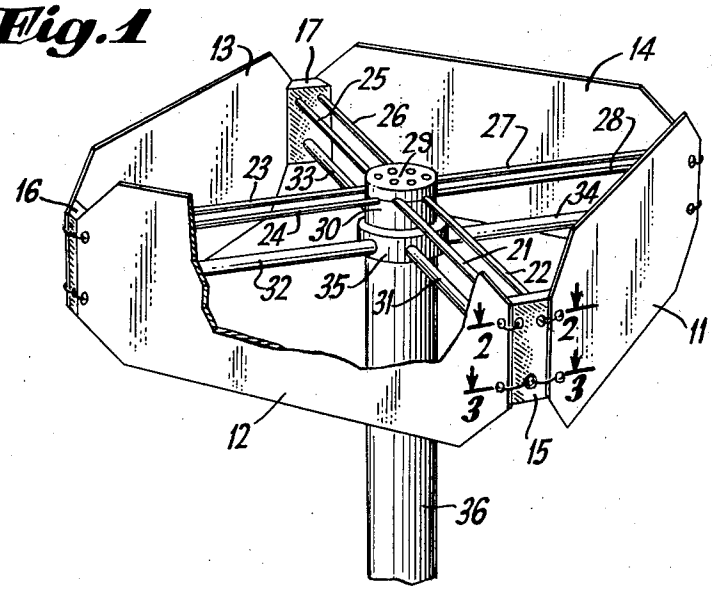


Fig. 2

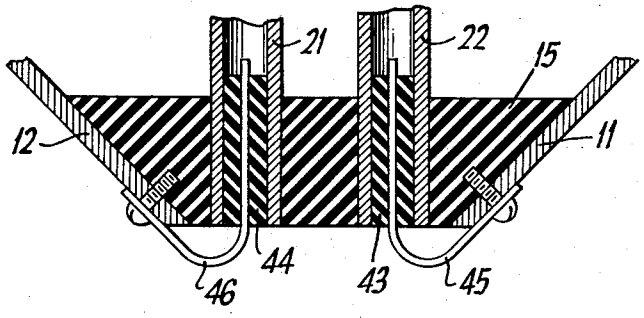
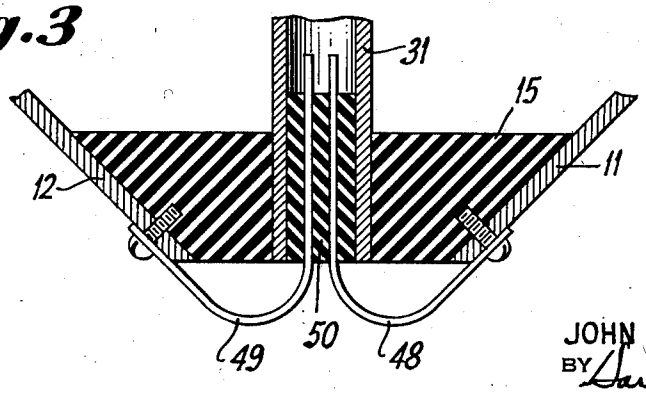


Fig. 3



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ANTENNA SYSTEM

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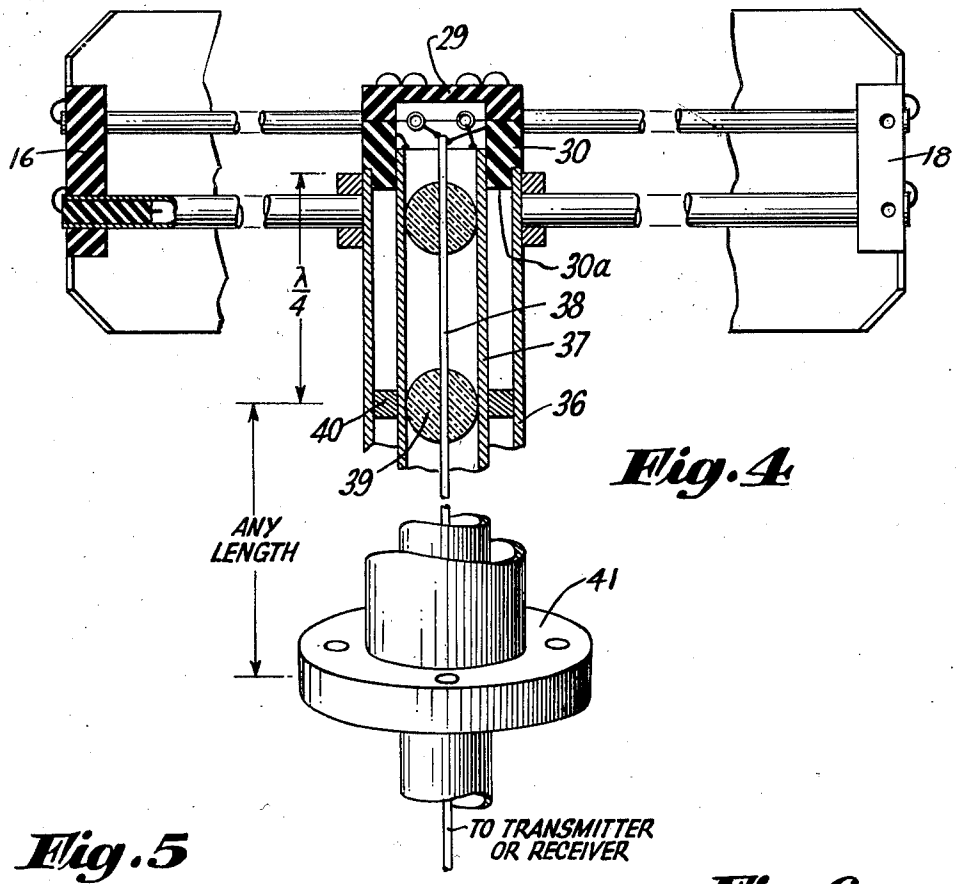


Fig. 4

Fig. 5

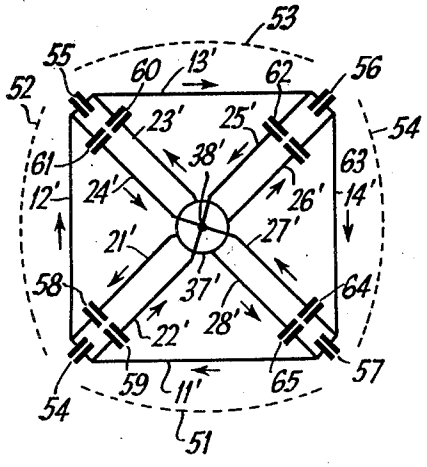
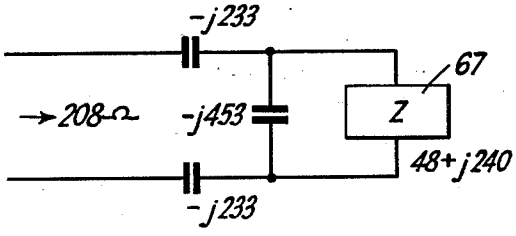


Fig. 6



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ANTENNA SYSTEM

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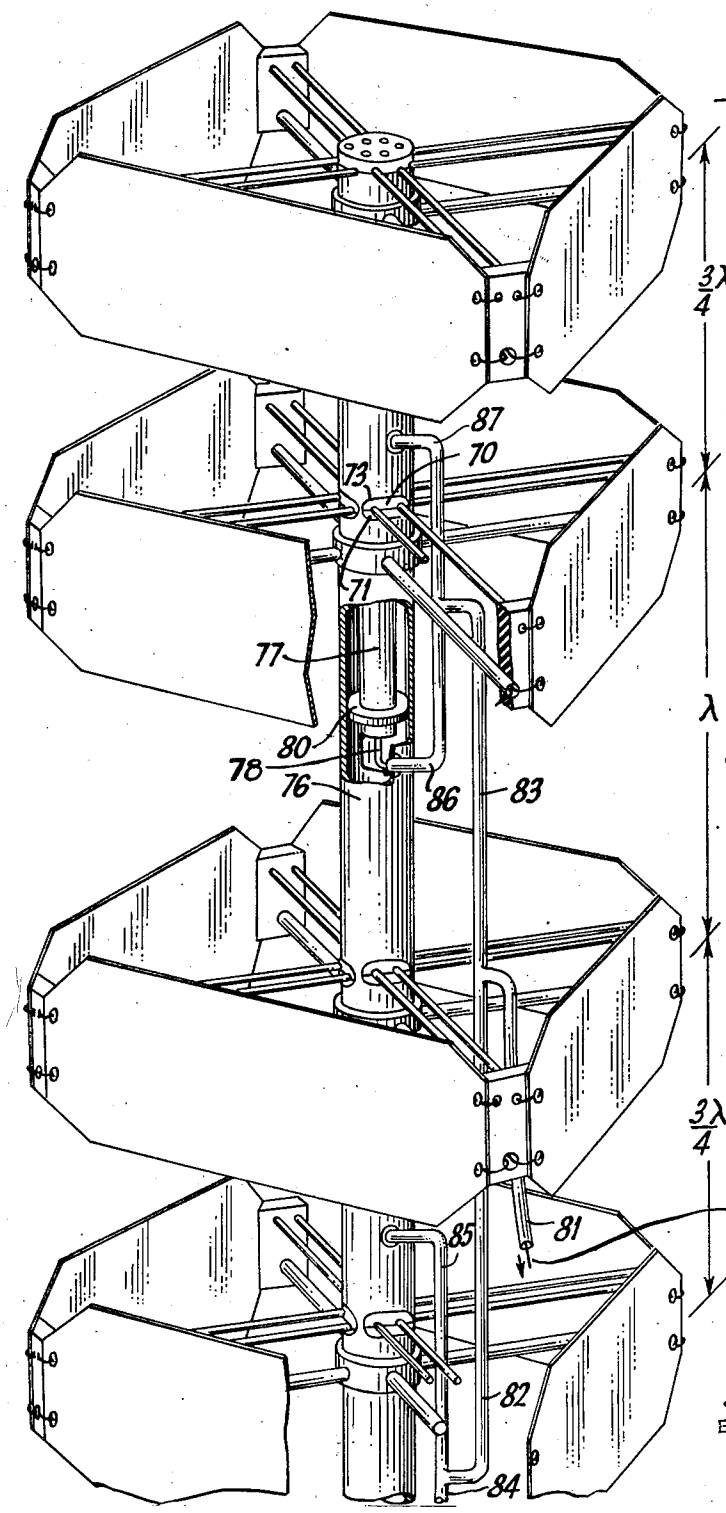


Fig. 7

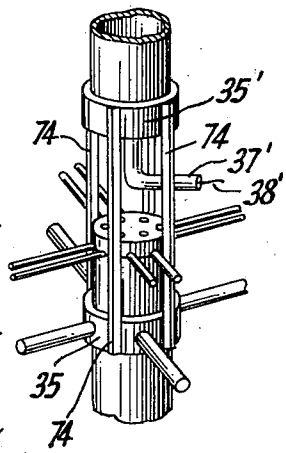


Fig. 7a

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Patented Nov. 18, 1952

2,618,746

UNITED STATES PATENT OFFICE

2,618,746

ANTENNA SYSTEM

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Application August 13, 1948, Serial No. 44,168

7 Claims. (Cl. 250—33.67)

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The invention relates to very high frequency antenna systems and particularly pertains to such an antenna system for producing a circular horizontal pattern for use in radio navigation applications and the like.

The subject antenna system to be described was designed primarily for transmitting use in radio aids to navigation; namely, for small radio-range systems known as "localizers" and omni-directional ranges popularly called "omni-ranges," however, the basic principles of the invention are equally applicable to such antennas for receiving only or for both transmitting and receiving purposes.

It is an object of the invention to provide a radio frequency radiator of horizontally polarized waves providing radiation substantially free from vertical polarization.

It is another object of the invention to provide a radio frequency radiator producing an essentially circular horizontal radiation pattern.

It is a further object of the invention to produce a radio frequency radiator of horizontally polarized waves producing a radiation pattern relatively independent of frequency.

It is still another object of the invention to provide a radio frequency radiator having broadband input impedance characteristics.

It is a still further object of the invention to provide an antenna system simple and economical in construction.

It is yet another object of the invention to provide an antenna system employing a matched feeder system thereby increasing the stability of the system as a whole.

It is yet a further object of the invention to provide an antenna system in accordance with the foregoing objects and capable of employment as a receiving antenna.

These and other objects of the invention will appear as the specification progresses.

According to the invention, the above objects are realized in a omni-directional antenna having a mechanical design economical in construction and neat in appearance and providing the desired electrical characteristics while avoiding electrical discontinuities inherent in antenna systems of the prior art. These objects are achieved in an antenna mechanically constructed to provide very short connections and symmetry that is unaffected by frequency and electrically connected to afford a feed system matched throughout thereby eliminating standing waves on any part on the feed system, a matching network further increasing the frequency band over which the input impedance of the antenna remains substantially unchanged, broad band radiator elements, and a novel means for coupling the radiating elements to the feed system.

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The invention will be described with reference to the accompanying drawing forming a part of the specification and in which:

Fig. 1 is a perspective view of an embodiment of an antenna system according to the invention,

Figs. 2, 3 and 4 are cross-section views showing certain detailed constructions of the antenna shown in Fig. 1,

Fig. 5 is a schematic diagram of the electrical connections of the antenna system according to the invention,

Fig. 6 is a schematic diagram illustrating impedance characteristics of one-quarter of the electrical system shown in Fig. 5, and

Fig. 7 is an illustration of an antenna array incorporating a plurality of antenna elements according to the invention, Fig. 7*a* showing details of an alternate construction thereof.

Referring to Fig. 1, there is shown an embodiment of an antenna system according to the invention constituted by radiator elements 11, 12, 13 and 14 arranged in a hollow square. Preferably, in order to secure broad band effects with elements of simple construction each radiator element is constituted by a rectangular sheet of metal, thereby forming a box-like structure, but conceivably within the scope of the invention they may be constituted by any conducting material in one of many desirable forms such as wire, hollow tubular forms, corrugated sheets, and so forth. The radiator elements are mechanically fastened together by means of insulating corner members 15, 16, 17 and 18 (the latter of which is hidden behind radiator element 11) which provide a small gap or separation between adjacent sides of the radiators at each corner of the square.

The radiating system described above is fed equally at each corner gap through four parallel wire lines 21—22, 23—24, 25—26, and 27—28 radiating from the center of the square. Each line is preferably constituted by two lengths of ⅜" diameter tubing spaced 1⅛" apart to provide a characteristic impedance of 208 ohms. The radiator elements are connected to the lines so that the direction of instantaneous currents flowing in the radiators of the antenna system is continuous around the perimeter of the square. As will be seen upon inspection of the drawing, the radiator elements are connected to the transmission line tubing by means of capacitive re-

actance elements only and are effectively insulated from the parallel wire line conductors at low frequencies and direct current. The transmission lines are connected in parallel at the center of the square to a coaxial feed line having the proper impedance to match the impedance of the parallel connected lines.

The radiator assembly formed by radiators 11 to 14 and insulating members 15 to 18 is supported by four mechanical support arms 31, 32, 33, 34 radiating from a central support 35 and terminating at insulators 15, 16, 17 and 18 respectively. The outer ends of the transmission lines are preferably fixed by apertures in the corner insulators, while the inner ends are preferably held in channel or grooves machined in contiguous surfaces of two cooperating insulating members 29 and 30 which are preferably clamped about conductors 21 to 28 of the transmission lines to hold them rigidly in place. Referring now to Fig. 4 in particular, it is seen that insulating member 30 is preferably provided with an annular boss portion 30a dimensioned to fix the position of members 29 and 30 with respect to the outer conductor 36 of a "single-end to balanced" transformer or "balun" unit, the inner conductors 37 and 38 of which constitute the feed line connected in parallel to transmission lines 21—22, 23—24, 25—26 and 27—28. Preferably, the inner conductors 37 and 38, held in spaced relationship by insulating beads 39 spaced along conductor 38, comprise a 52 ohm coaxial feed line to properly match the four parallel connected 208 ohm transmission lines. Outer conductor 36 of the "balun" also constitutes the mechanical support of the complete antenna system. In order that the mechanical support will not dissipate radio frequency energy, a shorting member 40 is interposed between conductors 36 and 37 of the "balun" unit at a point one-quarter wave from the uppermost end of the "balun" unit. As shown in Fig. 4 annular boss 30a of insulating member 30 and/or shorting member 40 constitute the sole means for spacing conductors 36 and 37 apart, however, additional spacer elements may be provided if desired. The portion of conductor 36 below shorting member 40 may be of any length and is preferably fitted with a mounting structure of any conventional or desirable construction, that shown here being a floor-flange 41.

According to the invention, in order to achieve optimum broad-band characteristics, standing waves that would normally be present, must be eliminated from the feeder system of the antenna. Since the actual impedance at each of the four gaps of the radiator elements differs considerably from that required to match the transmission lines properly, correct matching is achieved by coupling a small amount of capacity in parallel across each gap and a small capacity in series with each side of the transmission line immediately at the gap. This is readily accomplished both electrically and mechanically by a construction according to the invention hereinafter described.

Referring to Fig. 2, there is shown a cross-section of the construction of corner member 15 taken as being representative of all of the corner elements 15, 16, 17, 18 in a plane passing through the centers of conductors 21 and 22. Conductors 21 and 22 extend through corner member 15 to which radiator elements 11 and 12 are mechanically fastened, machine screws being shown in this instance although other mechanical fastening devices may be used equally as well. Concentrically disposed by means of insulators 43—44 in the transmission lines 21 and 22 are conductors 45, 46 respectively having lengths at which desired capacities are formed between conductors 22 and 45 and conductors 21 and 46. Conductors 45, 46 are connected at one end to the radiator elements 11 and 12, respectively as shown, thereby forming the capacitive elements according to the invention. Preferably, these capacitive elements are constituted in practice by short lengths of RG-11/U cable inserted into the transmission lines, although other methods of construction will be obvious to those skilled in the art.

Referring to Fig. 3, there is shown a cross-section of the same corner insulator 15 taken in a plane parallel to the cross-section of Fig. 2, but through axis of support arm 31. Here, two conductors 48, 49 are spaced within support arm 31 by an insulating medium 50 in the manner described above for the capacitive coupling elements. One end of each conductors 48 and 49 is connected to the adjacent radiator element 11 and 12, respectively as shown. Conductors 48, 49 have lengths at which the capacity there-between provides the desired parallel capacity to be coupled between the radiator elements according to the invention. Preferably, the parallel capacities are provided in practice by lengths of RG-22/U cable inserted into the ends of the horizontal support arms.

The electric circuitry of the antenna system above described can be represented by the schematic diagram shown in Fig. 5. Radiators 11—14 and transmission line conductors 21—28 are indicated by the corresponding primed reference numerals. The parallel capacities between radiator elements are represented by the conventional symbols for capacitors 54 55, 56, 57 and the series capacities by the symbols for, capacitors 58, 59, 60, 61, 62, 63, 64, 65. Thus, in this manner, a perfect match in each of the parallel lines is maintained for one desired frequency, preferably the frequency at the center of the selected frequency band. The current distribution on each of the four radiator elements is as shown by dashed lines 51, 52, 53 and 54. This symmetry of current distribution is maintained at all frequencies without adjustment by virtue of mechanical symmetry of the antenna. The result is a very nearly circular radiation pattern over an extremely wide frequency range. The type of matching network described is such as to further improve the broad-band characteristics of the antenna.

The mechanical and electrical characteristics of one typical antenna constructed according to the invention are as follows:

Center frequency	mc./s.	110
Input impedance	ohms	52
Transmission line impedance	do	208

Frequency band	Max. Standing Wave Ratio
2.5 mc./s.	1.2:1
4.0 mc./s.	1.4:1
6.0 mc./s.	1.6:1

Dimensions of radiator: 20" x 20" x 8" high.
Dimensions of radiator element: 18" x 8" (approx.).
Impedance at 110 mc./s.:

Radiator Impedance	48 ohms resistance 240 ohms inductive reactance
Parallel capacitors	453 ohms capacitive reactance
Series	233 ohms capacitive reactance

An impedance diagram of one-quarter of the typical antenna system is shown in Fig. 6 wherein the impedance of the radiator elements is represented by the block 67.

While the above described antenna was designed principally for use with radio aids to navigation, it will be obvious to those skilled in the art to employ it for radiating and/or receiving frequency modulated signals. In this connection it is considered desirable to provide additional vertical directivity by stacking several layers of radiators and feeding the same as shown in Fig. 7. Essentially the antenna structure of this figure is obtained by stacking four antennas as previously described in the vertical direction by any convenient means, perhaps the simplest being that shown in Fig. 7*a* wherein four angle members 74 are fastened, preferably by welding, to collar 35 in the interstices of the antenna structure. A second collar 35' is fastened to the other ends of members 74 and in turn is fastened to the outer conductor of the "balun" unit of the succeeding antenna element, whose inner conductors 37 and 38 are connected to a feed line 37' and 38' which is brought out in the space between the antenna elements and connected into the supply line as later will be described.

The preferred embodiment, however, is shown in Fig. 7 wherein a simple supporting member 76 supports all of the elements in the same manner as shown for the embodiment of Fig. 1. Insulating members 70 and 71 corresponding to members 30 and 31 are positioned in the interior of member 76 by any convenient means and the transmission lines led out through apertures 73 in the wall of member 76. A length of coaxial transmission line comprising coaxial conductors 77 and 78 is positioned as shown by means of a shorting element 80 corresponding to shorting element 40 of Fig. 4 to form a "balun" unit as previously described. The four "balun" units thus formed are connected by concentric transmission lines comprising coaxial line 81 bifurcated into lines 82 and 83 which are again bifurcated into lines 84 and 85 and 86 and 87 respectively. In this manner all of the "balun" units receive R. F. energy in the same phase. The spacing between layers of radiator elements is not very critical, depending somewhat on the number of such layers, and as a general rule the spacings are not all the same. It has been found that there is an optimum spacing for a given number of layers, that for four layers being one wavelength between the innermost layers and three quarter wavelength between the other layers. A further use of the antenna is contemplated for the radiation of television signals, for which use the size of the radiator elements are preferably increased, a change in the width of the elements being the preferable method, to provide the necessary additional band width required for the authentic transmission of the latter signals. The sides of the square can be increased to one-half wavelength and yet maintain the horizontal radiation pattern sufficiently circular for broadcast purposes.

While the invention has been described with reference to specific embodiments thereof, it is understood that modifications and alternative embodiments thereof will be obvious to the artisan without departing from the spirit and the scope of the invention.

I claim:

1. An antenna structure comprising a supporting member, arms radiating from said supporting member, electric insulating and spacing members arranged on said arms, conducting members bridged between adjacent pairs of said insulating and spacing members and arranged to form an interrupted geometrical figure about said supporting member, capacitive elements carried by said arms and connected across the interruptions between said conducting members, two-conductor transmission lines having ends thereof connected in parallel at a point substantially on the axis of said supporting member, and components carried by the conductors of said transmission lines to couple the remaining ends thereof capacitively to the ends of said conducting members.

2. An antenna structure comprising four radiating elements each short with respect to the operating wavelength, capacitive elements coupling said radiating elements at the ends thereof to define a substantially closed planar pattern, four two-conductor open transmission lines emanating from a central point within said pattern and extending directly toward adjacent ends of said radiating members, the conductors of each of said transmission lines being individually capacitively coupled to adjacent ones of said radiating elements at the ends thereof adjacent said capacitive elements, said radiating elements being insulated at low frequency from both of the conductors of said transmission lines and a primary transmission feeder connected to said transmission lines at said central point, said capacitive elements and said capacitive coupling of said transmission lines to said radiating elements having capacity values at which the impedance presented by the radiating elements is transformed to match that of the secondary transmission lines.

3. An antenna structure comprising a tubular supporting member, tubular arms radiating from said supporting member, electric insulating and spacing members arranged on said arms, electric wave radiating members bridged between adjacent pairs of said insulating and spacing members and arranged to form an interrupted geometrical figure about said supporting members, capacitors supported within said tubular arms and connected across the interruptions between said conducting members, tubular two-conductor transmission lines having ends thereof connected in parallel at a point substantially on the axis of said supporting member, and conductive members insulatedly supported within the tubular conductors of the remaining ends of said transmission lines to couple same capacitively to the ends of said electric wave radiating members.

4. An antenna structure comprising a tubular supporting member, tubular arms radiating from said supporting member, electric insulating and spacing members arranged on said arms, conducting plates bridged between adjacent pairs of said insulating and spacing members and arranged to form an interrupted geometrical figure about a center defined by the axis of said supporting member, conductors spaced within the ends of said tubular arms and connected across the interruptions between succeeding conducting plates to couple the same capacitively in end-to-end relationship, tubular conductor transmission lines connected in parallel at a locus on the axis of said supporting member, a coaxial transmission feeder spaced within said supporting member and coupled to said two-conductor transmission lines at said locus, the outer conductor of said coaxial feeder being connected to

said supporting member at a point substantially one-quarter wavelength at the operating frequency from the end thereof nearest said locus to form a balanced-to-unbalanced transformer, and conductors spaced within the ends of said tubular conductors of said transmission lines and connected to the ends of said conducting plates, said conductors having lengths at which the capacity between same and the tubular conductors serves to match the impedance offered by said transmission line to the impedance presented by said conducting plates.

5. An antenna structure including a tubular supporting member, and a plurality of radiating systems stacked in layers, each of said radiating systems comprising tubular arms radiating from said supporting member, electric insulating and spacing members arranged on said arms, conducting plates bridged between adjacent pairs of said insulating and spacing members and arranged to form an interrupted geometrical figure about a center defined by the axis of said supporting member, conductors spaced within the ends of said tubular arms and connected across the interruptions between succeeding conducting plates to couple the same capacitively in end-to-end relationship, tubular conductor transmission lines connected in parallel at a locus on the axis of said supporting member, a coaxial transmission feeder spaced within said supporting member and coupled to the two-conductor transmission lines of each of said layers at said locus, the outer conductor of said coaxial feeder being connected to said supporting member at a point substantially one-quarter wavelength at the operating frequency from the end thereof nearest said locus to form a balanced-to-unbalanced transformer, and conductors spaced within the ends of said tubular conductors of said transmission lines and connected to the ends of said conducting plates, said conductors having lengths at which the capacity between same and the tubular conductors serves to match the impedance offered by said transmission line to the impedance presented by said conducting plates.

6. An antenna system including a plurality of radiator elements arranged end-to-end to form a substantially closed hollow geometrical configuration, capacitive elements electrically intercoupling adjacent ends of said radiator elements, a plurality of two-conductor open transmission

line elements connected in parallel at a central point within said hollow configuration and extending outwardly from said central point directly to the adjacent ends of the radiator elements forming said configuration, there being one such transmission line element for each radiator element, means to couple a transmission line to said transmission line elements at said central point, and capacitive means intercoupling the ends of each of the conductors of said transmission line elements individually to the ends of adjacent ones of said radiator elements, said radiating elements being insulated at low frequency from both of the conductors of said transmission line elements, whereby said antenna system is operable over a relatively wide frequency band to produce a substantially circular radiation pattern.

7. An antenna system including four radiator elements arranged end-to-end to form a substantially closed hollow square, capacitive elements electrically intercoupling adjacent ends of said radiator elements, four two-conductor open transmission line elements connected in parallel at a central point within said hollow square and extending outwardly from said central point directly to the corners of said square, means to couple a transmission line to said transmission line elements at said central point, and capacitive means intercoupling the ends of each of the conductors of said transmission line elements individually to the ends of adjacent ones of said radiator elements, said radiating elements being insulated at low frequency from both of the conductors of said transmission line elements, whereby said antenna system is operable over a relatively wide frequency band to produce a substantially circular radiation pattern.

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