This invention relates generally to high frequency antennas and more particularly is concerned with a vertically polarized high frequency collinear array, i.e., one in which there is a plurality of simultaneously fed radiating elements arranged end to end along a vertical line.

It is known that the arrangement of antennas defined as an array provides increased directivity which is usually accompanied by increased gain. In the antenna art where it is desired to operate at high frequencies, say of the order of a few hundred megacycles, every advantage of gain and directivity must be taken especially where only low power is used. Where complete coverage of an area is desired, symmetry of radiation pattern is also essential. The object of my invention is a high gain antenna with relatively sharp directivity, and by virtue of the novel construction I have devised, the pattern is maintained with extremely good symmetry in the horizontal plane. The construction is such that practical embodiments of the antenna can be constructed with great economy and ease.

The particular configuration of my antenna, i.e., its arrangement of electrical elements has been described in U.S. Patent 1,957,949, issued May 8, 1934 to C. S. Franklin, and in certain British patents referred to in said U.S. patent. The basic construction comprises a vertical arrangement of half-wave elements separated by phasing sections so that the currents in all of the half-wave elements will be in phase. The phasing elements may be quarter-wave loops or bends arranged at right angles to the Junctions between half-wave elements, in which case the phasing sections are not radiating in character. Franklin taught the use of intermediate half wave sections so that at least a portion of each intermediate section serving as a phasing section was radiating in character in the same phase as the principal radiating elements for reinforcement.

In order to achieve a good pattern and efficient radiation from an array, whether vertical or horizontal, it is desirable that the same be fed from its center. Symmetry is achieved in all respects. Obviously since the portion of a pattern from a horizontally polarized antenna directly beneath the antenna is of no importance, it is a simple matter to feed such an array, and horizontally collinear arrays are in extensive use. In the case of the vertically polarized array, however, the problem is one which has not been satisfactorily solved so far as I am aware, until my present invention. The reason for this is two-fold. In the first place the transmission line which is to feed the vertical array from the center thereof is required to extend up to the center point of the antenna parallel to the lower radiating elements. The result would be a destruction of the omnidirectional nature of the antenna array, a characteristic which is one of the principal desiderata of the vertical array, and the excitation of the transmission line would cause undesirable high angle radiation. The patentee of the above referred to patent proposed feeding the collinear array from an end thereof when arranged vertically, but the resulting radiation pattern is neither symmetrical, nor is the maximum efficiency of the antenna utilized. Furthermore, such a feed imposes restrictions on the band width.

The second difficulty with feeding a vertically polarized collinear array has been the practical problem of supporting the elements in their proper relationship. Metal masts are sources of radiation interference and masquerading.

Because of the above, it has been customary to utilize complicated vertically polarized arrays which are not collinear. The usual method is to mount a plurality of dipole elements, all fed individually, about a vertical mast which in turn is supported from a metal structure. The expense of these structures has been to a great extent responsible for the suppression of widespread use of many communication mediums which would otherwise be available. This is especially true in the 400 to 500 megacycle range, where it is necessary to cover an area in all directions from a central location, as for example in taxicab, police, fire, and commercial two-way communication.

In all of the discussion herein, it is desired to point out that while the principal use of the antenna described is for transmission, same is likewise suitable, and the invention desirable, for reception as well. Furthermore, the frequencies referred to herein are not exclusive, although the problems arise perhaps more sharply in the range referred to.

The principal object of the invention is to provide an antenna structure which will comprise a vertically polarized collinear array in which the antenna is fed at the center thereof and the transmission line providing the feed will in no way affect the radiation pattern or efficiency of the antenna.

Another object of the invention is to provide a novel construction for supporting the antenna along its full length.

A further object is to provide a novel arrangement for mounting the antenna upon a rigid mast or the like which will not interfere with the radiation pattern of the antenna.

I recognize that the physical principles upon which the invention are based are not new, and further that the arrangement of the collinear array to produce a certain theoretical result has been known, but I desire to emphasize that the achievement of a practical embodiment has been possible only by virtue of the invention herein, and I consider such an achievement one of the important objects of the invention.

In connection with the results achieved, other objects of the invention are concerned with the extreme simplicity and economy of the structure which I have disclosed herein. The antenna array is formed of simple end to end dipole elements, easily formed without expensive tools, dies or fixtures; the transmission line feeding the antenna connects only at the center thereof, i.e., at one point, and is contained totally within the lower half of the antenna physically located inside of the radiating elements (as a matter of fact it is a part of such lower half); the support for the antenna is non-metallic and easily rendered air-tight and waterproof while being simply formed of readily available materials without the use of complicated or expensive equipment; the mounting.
of the antenna is simple and economical, and through the use of simple isolation sections rendered non-interfering with the radiating portions of the antenna. As will be described hereinafter, the mounting of the antenna is achieved by securing the bottom end of the radome to a rigid metal mast, with the coaxial cable end on the interior of the mast if desired, and with an isolating quarter wave section either secured to the coaxial cable on the inside of the radome or on the outside of the mast or as a part of the mast.

In the figures the relative proportions of conductors and cables are exaggerated for clarity.

In Fig. 1 I have illustrated a simple form of vertically polarized collinear array. There are three half-wave sections 20, 21, and 22 connected to one another by two quarter wave phasing sections 23 and 24. The section 23 is connected from the lower end 25 of the half-wave section 20 to the upper end 26 of the half-wave section 21. The section 24 is connected from the lower end 27 of the half-wave section 21 to the upper end 28 of the half-wave section 22. Each of the quarter-wave sections 23 and 24 is formed as an open loop or U-shaped bend and the directions of the currents in the parts of the loops is such as to prevent radiation therefrom. The sections are however effective as half-wave lengths of the antenna to space the radiating sections electrically and thereby cause the standing waves in the radiating sections 20, 21 and 22 to be in phase.

It will be noted that I have shown the center of the half-wave element 21 opened as at 39 to permit the connection of a feed transmission line thereto, but no such line is shown for reasons to be explained. Presuming that the antenna of Fig. 1 is fed at its center, the pattern will be generally toroidal, with the circular dimension occurring in the horizontal plane, its axis being coincident with the vertical axis of the antenna. Such an antenna is omnidirectional, and its vertical pattern is quite narrow. Actually the beam may be made less than twenty degrees in width for a five element antenna. By slight variation of the length of the sections, the beam may be diverted slightly upward or downward, depending upon the purpose for which the antenna is to be used.

It is obvious that in order to connect a transmission line to the opening 30 it will be necessary to bring the electrical leads up from the bottom of the antenna, since the antenna must be mounted at its bottom. This line parallel to the antenna would destroy the pattern and generally interfere with the radiation from the antenna. It is also obvious that in order to support and maintain the configuration of the antenna and its sections some manner of support is required. If metallic, again the radiation pattern will be interfered with, and the efficiency will be decreased.

I have been able to provide such a feed as will not in any way affect the radiation pattern or decrease the efficiency of the antenna. This will be described shortly.

In Fig. 2 I have shown another form of the vertically polarized collinear array, but in this case the phasing sections provide some radiation, and the physical space occupied by the antenna in a horizontal plane is less than that of the antenna of Fig. 1. Thus, there are three half-wave elements 31, 32 and 33. There are connecting phasing sections 34, one of which is shown in section 34 extending from the bottom end 35 of the element 31 to the top end 36 of the element 32, and the section 37 extending from the lower end 38 of the element 32 to the top end 39 of the element 33. The total length of each of the sections 34 and 37 is $\lambda/2$. A substantial portion of each of the phasing sections 34 and 37 is reversed in direction relative to the principal elements 31, 32 and 33, and hence, since the current in the phasing sections is of reverse polarity, there will be at least a small amount of reenforcing radiation from each of the phasing sections.

Fig. 3 illustrates an antenna substantially the same in configuration as that of Fig. 2. The only exception is...
in the fact that the vertical placement of the elements 31, 32 and 33 of Fig. 2 is such that adjacent element ends lie in the same horizontal plane, while in the antenna of Fig. 3, the ends of the elements 40, 41 and 42 which are the principal radiating elements. These are connected by phasing sections 43 and 44 of S configuration, each λ/2 in total length, but it will be noted that the points of connection 45 and 46 are spaced more above the other, and the same is true for points 47 and 48.

In both Figs. 2 and 3, the center element is opened for connection at 50 and 51 respectively but again no connection with a transmission line is shown. It is not intended to infer by the illustration of the center fed antennas of Figs. 1 to 3 that such antennas have successfully been center fed. As a matter of fact, prior to my invention the contrary has been true. The center feed has been illustrated and referred to in order to show the electrical equivalents of the antennas of Figs. 4 to 6 inclusive.

In Figs. 4 to 6 inclusive I have illustrated the application of my invention to the three antennas respectively of Figs. 1 to 3 inclusive. In every case illustrated, the lower half of the antenna is the exterior surface of the outer conductor of a coaxial cable, the upper half is the bared extension of the central conductor of the same coaxial cable, or of a coaxial transmission line. Thus, the transmission line is the inside surface of the cable combined with the contained portion of the central conductor.

To illustrate this arrangement, I have shown in Fig. 7 a conventional dipole formed of quarter-wave elements 60 and 61 connected to a transmission line 62 and 63 at the points 64 and 65. The use of a coaxial cable having an outer conducting sheath for forming the same dipole antenna is shown in Fig. 8. The identical reference characters are applied to the same functional parts. Thus, the right half of the dipole 61 is the bared extension of the central conductor of the coaxial cable 67; the outer surface of the outer conductor 68 is the left hand half 60 of the dipole; the one conductor 62 of the transmission line is the inside surface of the conductor 68 with the connection 64 being the end of the outer conductor 68 at the center of the antenna, where same has been cut away to bare the extension of the central conductor; and the second conductor of the transmission line 63 is the shielded portion to the left of the end 64. The juncture 65 is represented by the point at which the central conductor 61 emerges from the insulation 69. In order to carry forward the explanation, a break 71 is shown in outer surface 60 to indicate the left hand end of the left half of the dipole. This is intended to signify that the portion of the cable to the left of the break 71 is not energized for radiation. In practice this is achieved by the connection of a quarter-wave insulating section at this point, as will be pointed out, which has no effect upon the interior of the cable insofar as transmission properties are concerned.

Returning now to Fig. 4, it will be seen that the antenna there illustrated is the equivalent of the antenna of Fig. 1. The element 20, quarter-wave phasing section 23, and the upper half of the element 21 are the equivalent of the coaxial cable 75 or are formed of a wire connected thereto, and are bent to the same configuration as those of the antenna of Fig. 1. The coaxial cable 75 is bent to the lower configuration of the antenna from the point 30 downward, and forms the lower half of the element 21 as well as the section 24 and the elements 25, 26, 27 and 28 are now merely bends. The connection at 30 is as shown at 64 and 65 in Fig. 8. An isolating sleeve 76 of λ/4 length is electrically engaged to the outside of the outer conductor of the coaxial cable, one quarter-wave down the lower element 22. Thus, the radiating surface of the lower element is the upper half thereof and the outer surface of the sleeve 76, the inside thereof presenting a very large impedance to the remainder of the coaxial cable thereby isolating the antenna portions at the spaced apart elements. Thus, antenna of Fig. 3 is formed of half-wave elements 40, 41 and 42 which are the principal radiating elements. These are connected by phasing sections 43 and 44 of S configuration, each λ/2 in total length, but it will be noted that the points of connection 45 and 46 are spaced more above the other, and the same is true for points 47 and 48.

As far described, the invention is embodied in the formation of the antenna and the transmission line out of the coaxial cable. I am aware that the use of the arrangement shown in Fig. 8 to provide a center fed dipole has been known, but to my knowledge and belief the formation of a vertically polarized collinear array out of coaxial cable has not heretofore occurred to those skilled in the art, nor has it been apparent that a vertically polarized collinear array could be center fed by any means not destructive of the omnidirectional pattern or not of a character to decrease antenna efficiency.

Throughout this specification, I have only shown and described arrangements made up of an odd number of principal radiating elements, but this is not intended to exclude the application of the invention to arrays formed of even numbers of radiating elements. In the case of the odd element array, the transmission line is connected at the center of a half-wave element and hence located at a point of low impedance, which is preferable for most coaxial cables. In the case of even element arrays, the connection would have to be made at a juncture between the ends of two dipoles, a point of relatively high impedance, so that great mismatch would occur without the use of some method of transformation. This is impractical when coaxial cable is used to form the antenna, but it is feasible.

The antenna formed as described is easily supported throughout its length by inexpensive means. In Fig. 9 I have shown a practical form of the antenna utilizing seven principal radiating elements, and six interconnecting phasing sections of type shown in Figs. 2, 3, 5 and 6. In forming this antenna completely from coaxial cable, first the coaxial cable 90 is bared from the feed point 91 to the free end 92. The various elements are bent 93, 94, 95, 96, 97, 98 and 99 half element 99 from the bared central conductor, and the half element 100, the elements 101, 102, 103, 104, 105 and 106 from the body of the coaxial cable. In case the upper portion is formed of an additional conductor, the two halves may be joined at 91 either before or after bending. Any simple method of forming the antenna may be used. For example, wooden or metal jigs may be prepared, and the cable merely inserted in the jigs and removed after formation. The geometrical configuration is exactly as shown in the figure with proper precautions being taken to assure appropriate dimensions for the frequency to be used. The principal radiating elements are 93, 94, 95, 97, 99—100; 102, 104 and 106. The lower half of the element 106 is provided with an isolating sleeve 108 whose purpose is to prevent standing waves in the coaxial cable 90 below the element 106. This entire configuration, including the sleeves 105, is molded into an elongate rod of some insulating material 109 whereby it retains its configuration. The insulating material 109 can be any of the well-known substances having good dielectric properties. Thus, it can be any of a large number of plastics, preferably of the thermostatting types, such as "Bakelite" or other phenyl condensates. Recently developed substances known as polyester resins are ideal because of their great strength and substantial absence of radiation properties.

As seen, a radome 110 is formed having a simple lead or pigtail protruding from the bottom thereof. This could even be of considerable length, the antenna elements having been formed and encased on the end of a relatively long piece of coaxial cable. The radome is now suitably mounted in any desired manner, such as
by inserting same in the end of a steel cylindrical mast 112 and fastening same by bolts 113. The outer con- 
ductor of the coaxial cable 122 is of course grounded to the mast as indicated by the jumper 114.

In Fig. 14, such an antenna is shown with the mast secured to a base or standard 115 which in turn is sup- 
ported upon a tower or the like. In this modification, instead of completely enclosing the antenna elements, 
the uppermost element 93 is not molded into the radome but is left protruding much like a "buggy whip" an- 
tenna. This reduces weight and cost of the antenna, and is practical because the upper element 93 may be made as 
stiff as desired and have its lower end well embedded in the body of the insulating material 109.

In Figs 10 and 11 I have shown two modifications of 
the antenna construction, utilizing different forms of 
support. In Fig. 10 the antenna which is designated gen- 
erally 120 is preformed as the antenna of Fig. 9 and is dis- 
posed in an elongate slot formed in an elongate insulating 
plug 121. The plug 122 is of sufficient length to pro- 
tect the antenna throughout its entire extent. The co- 
axial cable 123 is shown protruding from the bottom of 
the plug. As will be noted in Fig. 12, the plug is gen- 
erally of rectangular cross section, and the slot 121 is of 
rectangular cross section as well. The sectional view 
12—12 is taken through the antenna at one of the phas- 
ing elements of the invention, hence three equivalent 
sections shown in the slot at 124, 125 and 126. This might be a 
sectional view through the phasing section 105 of Fig. 9.

The insulating plug 122 is preferably formed of any 
material of good dielectric properties. I have used wood 
with success, but I prefer other materials such as for 
example, a cellulose acetate, various resins, plastics, 
and the like. The cellular or "foamy" acetate is excel- 
scent because it is easy to work, light in weight, and 
relatively firm. This plug may be later molded into a 
radome much as described in connection with Fig. 9, 
or the radome 125 may be formed upon the plug by en- 
wrapping the same with fabric formed of glass fibres 
which have been impregnated with a hard-setting liquid 
polyester resin. It is economical also to preform the 
radome by any desirable method, thereafter assembling the 
plug 122 therein, closing off the ends by means of 
suitable discs such as shown at 126 and then impregnating the entire assembly with the polyester resin to seal 
the antenna within the radome.

In Fig. 10, the outer sleeve 127 has a depending skirt 
129. Instead of using an isolating section within the 
radome, the mast 131 has an end plate 132 secured by 
welding it or the like, and by means of which a concentric 
sleeve 133 is secured thereto. The sleeve 133 has an 
outer diameter such as snugly to fit within the radome 
skirt 129 and is secured thereto by blind rivets 134. The 
sleeve 133 is one-quarter-wave long and its upper end is 
electrically connected with the outer conductor of the co- 
axial cable. This construction provides a shorter radome 
than the embodiment of Fig. 9, and combined with a 
construction as shown in Fig. 14 in which the upper- 
most element is a "buggy whip" the length of the radome 
can be made even shorter. It is to be understood that the 
coaxial cable makes electrical contact with the 
plate 132.

Still a further modification of the antenna support- 
ning means is shown in Fig. 11. Here an antenna 140 
is preformed from the coaxial cable 141 and is provided 
with spacers 142 along the length thereof. The antenna 
is disposed in a prefabricated radome 143 and may be 
sealed into the radome by the use of suitable plugs and 
liquid polyester resins or other equivalent material. In 
the illustrated example, the bottom end of the radome 
is flanged as at 144 and the flanged end is screwed to a 
plate 145 by screws 146. The upper end of the mast 
147 is also flanged as at 133 and the lower end flange as 
well, sandwiching the plate 145 between the flanges. The cable 141 electrically engages the plate 
145 and it will be seen that this point of engagement 
is less than a quarter-wave length from the phasing sec- 
tion 148. An outer sleeve 149 is secured as by welding 
to the circumference of the plate 145 thereto. At a dis- 
tance equal to one quarter-wave length below the phas- 
ing section 148, I locate a shorting disc 150 on the in- 
terior of the sleeve 149 between the mast 147 and the 
interior of the sleeve, and the sleeve 149 extends below 
this point a distance equal to a quarter-wave. Thus, the 
lower portion of the inside of the sleeve serves as the 
isolating section, while the entire exterior of the sleeve 
plus the small part 152 of the coaxial cable below the 
section 148 serve as the lowestmost of the principal radiat- 
ing elements of the antenna 140.

The number of elements used is not in any way lim- 
ited by the illustrations herein, but rather is controlled 
by the practical problem of suitable dimensions for the 
frequency being used. Wind loading height above the 
ground, beam width desired, and many other factors may 
influence the number of elements used and their spacing, 
but these and other details are of no effect upon the 
operation and performance of the invention as hereinafter 
explained.

With respect to the materials from which I have suc- 
cessfully produced the structures described herein, I have 
utilized as the glass fibre fabric a material known as 
"Fiberglas" cloth woven by various mills throughout the 
United States which utilized glass fibres produced by 
Owens-Corning Fiberglas Corporation of Toledo, Ohio. 
The impregnating material comprises a polyester resin 
known as "Selectron 5003" manufactured and sold by 
Pittsburgh Plate Glass Co. of Milwaukee, Wisconsin. 
Other similar materials are suitable and will occur to 
those skilled in the art.

Obviously many variations and changes can be made 
in the construction of the invention without departing 
from the purview of the invention as described herein. 
It is desired also to point out that the theory set forth 
wherein the operation of the antenna is explained is only 
by way of assistance towards an understanding of the 
invention and not by way of limitation.

I claim:
1. A high frequency vertically polarized antenna for 
providing a substantially omnidirectional radiation pat- 
tern and mounting thereof comprising, a plurality of 
substantially collinear vertically arranged radiating dipole 
elements, half-wave phasing sections connected between 
dipole elements, all of said dipole elements and phasing 
sections being preformed as an integral unit, the bottom 
half of said unit comprising a coaxial cable having an 
outer conductor and an inner conductor and the cable 
being bent to the configuration of the dipole elements 
and phasing sections of the lower half, the upper half of 
the antenna comprising an extension of the center 
conductor of the cable from the midpoint of the antenna 
upward, and the inner surface of the outer conductor as 
well as the inner conductor from the midpoint downward 
comprising a transmission line connected to the vertical 
electrical midpoint of said antenna, a single sealed hous- 
}
a rigid metal standard sealed with and secured coaxially to
the bottom end of said housing.

2. An antenna as claimed in claim 1 in which said
retaining means comprises a cellular plastic core having
recessed means seating said antenna unit in said pre-
formed integral condition.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,874,983</td>
<td>Hansell</td>
<td>Aug. 30, 1932</td>
</tr>
<tr>
<td>1,987,949</td>
<td>Franklin</td>
<td>May 8, 1934</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ponte</td>
<td>May 18, 1937</td>
</tr>
<tr>
<td>2,080,577</td>
<td>Von Baeyer</td>
<td>Feb. 24, 1942</td>
</tr>
<tr>
<td>2,274,389</td>
<td>Von Baeyer</td>
<td>Sept. 29, 1942</td>
</tr>
<tr>
<td>2,297,512</td>
<td>Bailey</td>
<td>Oct. 13, 1942</td>
</tr>
<tr>
<td>2,298,449</td>
<td>Roosenstein</td>
<td>Feb. 16, 1943</td>
</tr>
<tr>
<td>2,311,472</td>
<td>Adock et al.</td>
<td>Mar. 3, 1953</td>
</tr>
<tr>
<td>2,630,530</td>
<td>Webster</td>
<td>June 15, 1954</td>
</tr>
<tr>
<td>2,681,412</td>
<td>Great Britain</td>
<td>Aug. 18, 1932</td>
</tr>
</tbody>
</table>