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Bogner

[11] **3,821,745**

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[54] **TRANSMITTING ANTENNA EMPLOYING PARASITIC END-FIRE DIRECTORS**

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[21] Appl. No.: **175,999**

[52] **U.S. Cl.**..... **343/770,** 343/833, 343/891, 343/912, 343/914

[51] **Int. Cl.**... **H01q 13/10,** H01q 19/00, H01q 1/12

[58] **Field of Search** 343/727, 770, 771, 833, 343/890, 891, 912, 914

[56] **References Cited**

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[57] **ABSTRACT**

A transmitting antenna assembly comprises elementary driven antenna elements and end-fire directors on a conventional supporting structure to obtain an omnidirectional or other desired antenna pattern, even for supporting structures of relatively large transverse dimensions. The end-fire directors employ one or more conductive members wherein one portion of the member is transverse to the director axis and another portion thereof is bent at a substantial angle from its normal transverse position.

14 Claims, 5 Drawing Figures

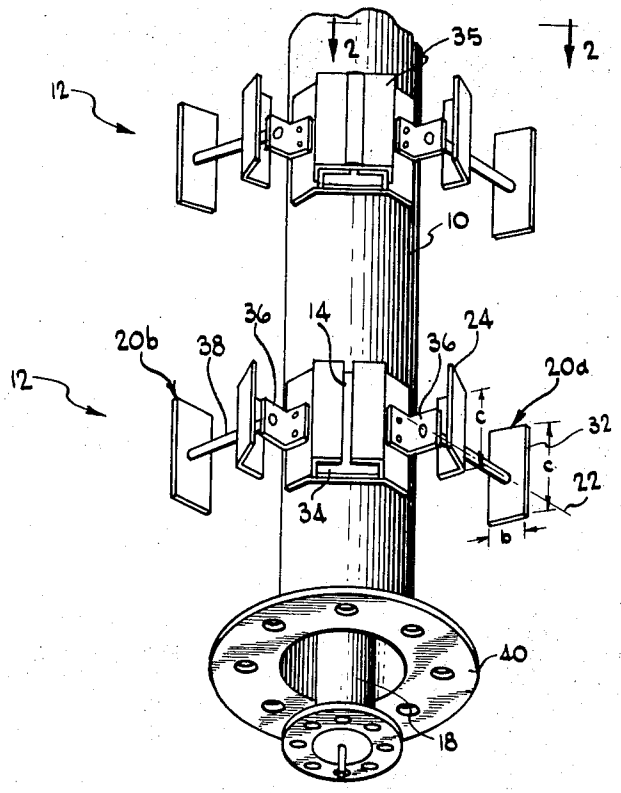
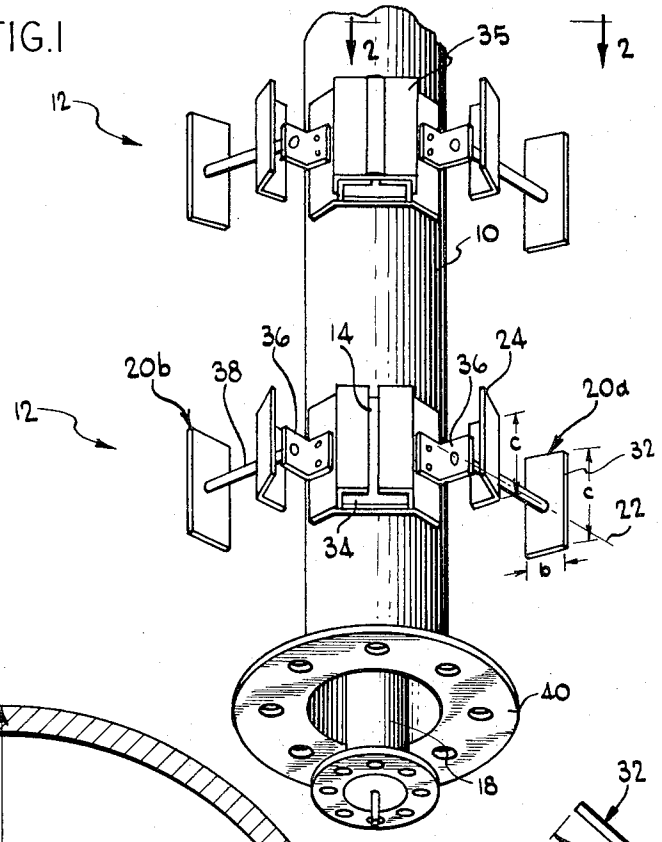


FIG.1


2
35
2
12
10
36
14
24
20b
38
36
20a
12
c
32
c
22
34
b
10
40
18

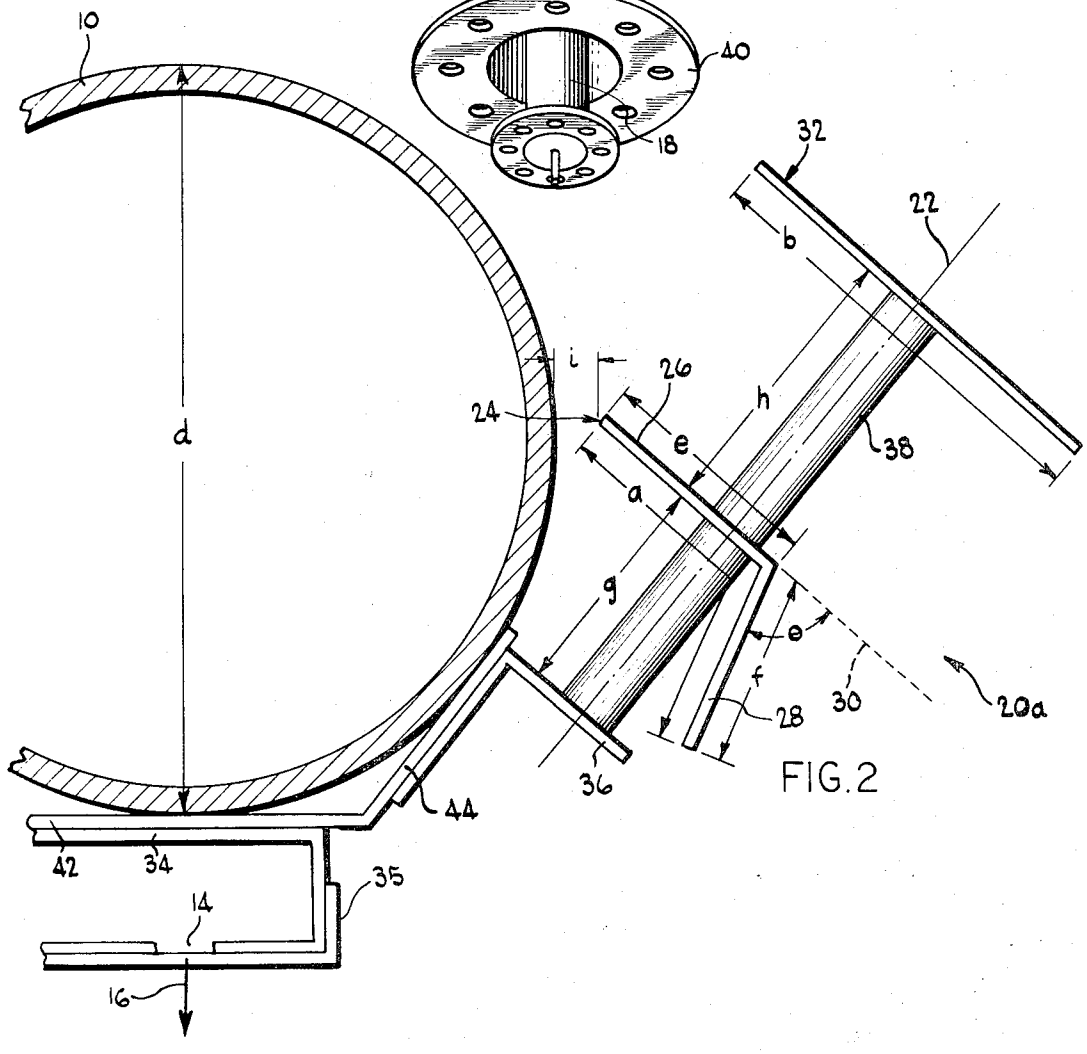

32
22
b
i
26
24
h
e
38
d
a
g
e
f
28
30
20a
36
44
42
34
35
14
16

FIG.2

FIG.3

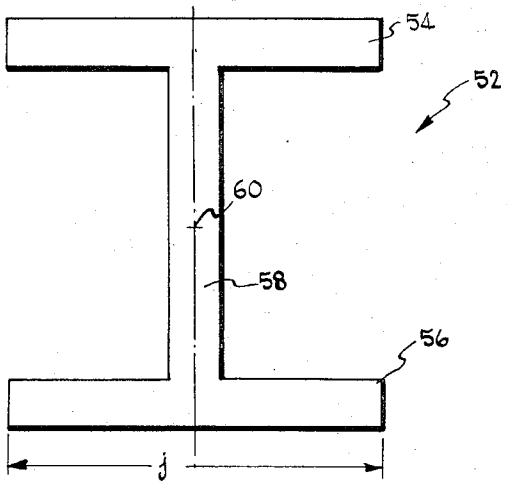


FIG.4

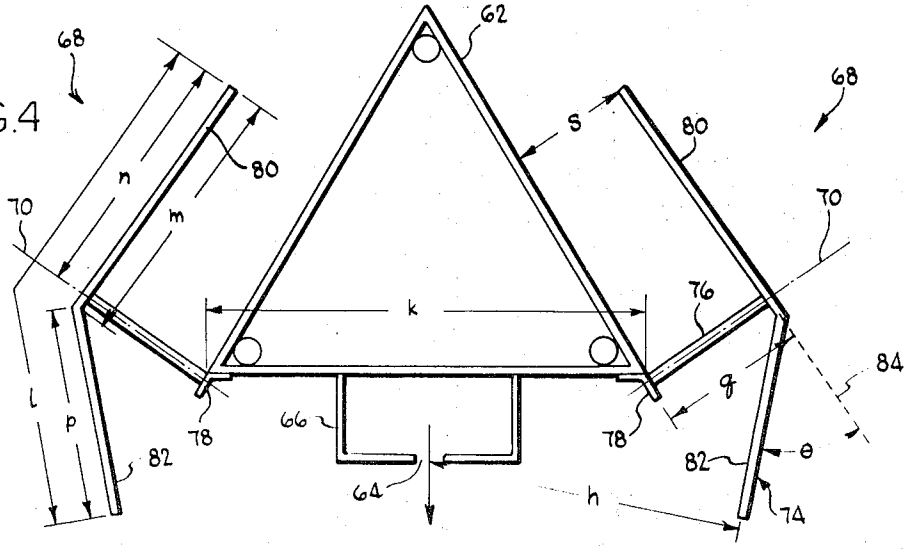
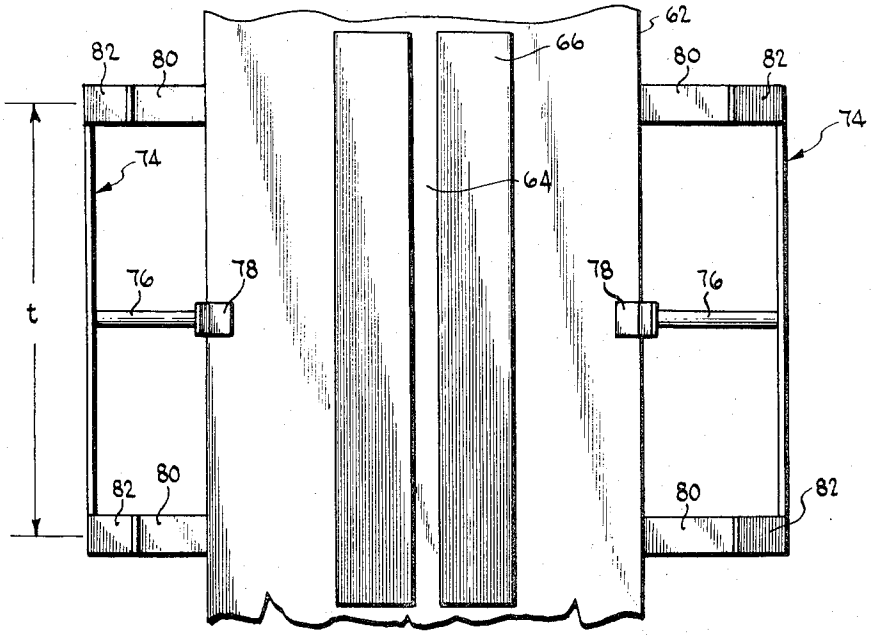


FIG.5



TRANSMITTING ANTENNA EMPLOYING PARASITIC END-FIRE DIRECTORS

The present invention relates to antennas employing end-fire parasitic elements, and more particularly to such antennas for television broadcasting.

In the design of transmitting antennas for television broadcasting, and especially for UHF-TV frequencies (e.g., 470 mHz. to 890 mHz.), it is generally desired to achieve high gain with an omnidirectional pattern (or a pattern of some other desired shape) in the azimuth plane at minimum cost. For omnidirectional performance, the total or maximum signal strength variation as a function of azimuth plane direction cannot be more than approximately 3db (± 1.5db) in accordance with trade acceptance and FCC standards, and such an antenna pattern is very often required by a broadcasting station providing service to a given region or community.

To achieve a high overall antenna gain, it is the usual practice to vertically stack a large number of driven antenna elements, each one defining a "bay," to typically provide a vertical array extending for 20 to 50 feet, or more. In view of the substantial vertical height thus needed, the supporting structure, typically a metal tower or mast pole, on which the elementary driven antenna elements are supported, will generally be made with a relatively large diameter. That is, the supporting structure will generally have a major transverse dimension greater than one-quarter wavelength, at the transmitted frequency, to provide the strength and rigidity necessary to mechanically support the antenna assembly and maintain stability in the wind and weather conditions to which it may be subjected. However, a relatively large diameter supporting structure, (e.g., of about a quarter wavelength or greater) generally produces a so-called "shadowing" effect on the resulting antenna pattern, and due to this effect a simple, single vertical array of driven antenna elements on such a supporting structure will not ordinarily provide the omnidirectional, or other desired shaped pattern required for a particular broadcasting application.

In U.S. Pat. No. 3,587,108, of the present inventor, there is disclosed and claimed an antenna assembly structure for achieving an omnidirectional or other desired pattern with a single vertical linear array of elementary antennas mounted on a large diameter structure of any conventional construction, wherein the assembly generally comprises the supporting structure, a driven antenna carried by the supporting structure and defining a radiation axis extending therefrom, and at least one end-fire parasitic director carried by the supporting structure. The end-fire parasitic director, in accordance with a preferred embodiment of that patent, has a longitudinal axis and comprises discrete planar conductive plates disposed in spaced parallel relation along that axis and arranged normal thereto. The discrete conductive plates have their respective major dimensions at least a quarter-wavelength in the plane of the electric field vector of the transmitted signal, and each director is positioned relative to the driven antenna and supporting structure so as to alter the shape of the antenna pattern produced by their combined effects to provide the selected overall antenna pattern for the assembly. One or more of such parasitic directors may be employed, as desired, in combination with the supporting structure and driven elements to produce

any number of pattern shapes, from omnidirectional to highly directional, and these are described in detail in the aforementioned patent, the subject matter of which is hereby incorporated into the instant application by reference thereto.

Because of the high gain, and consequent great height, requirements of such antenna assemblies, it is often necessary, as previously indicated, to make the transverse dimension of the support structure, such as the diameter of a supporting mast or pipe, or the equivalent dimension of triangular or other shaped towers, not only greater than a quarter wavelength, but at least one-half wavelength or more. And in particular, it should be noted here that although omnidirectional performance is the most common requirement for broadcast antenna designs, it is generally the most difficult criterion to meet. Antennas requiring directive performance are almost always easier to design. Thus, omnidirectional performance is typically the governing design criterion, and because of shadowing effects, the principal controlling parameter is the support mast size (in wavelengths).

In practice, conventional steel pipe is commonly employed for the supporting mast since it is relatively inexpensive and can be flanged, whereas "high strength" steels cannot. Consequently, from practical design considerations, such mast pipes for UHF broadcasting, for example, are commonly required to have diameters of from one-half to three-quarters wavelength, based on existing transmitter tube powers, FCC rules on effective radiated power (ERP), yield strengths of the steel, considerations regarding the power handling characteristics of the coaxial feed lines located inside the pipe, etc.

Although with mast structures of less than one-half wavelength diameter, it may be practical in many antenna designs according to the teachings of the aforementioned patent to use only two plates per end-fire director to achieve an omnidirectional pattern, for mast structures having diameters larger than one-half wavelength a greater number of plates per director is generally required to maintain the same omnidirectional performance. However, it has been found that as the mast diameter is increased, which generally increases the required number of plates per director, undesirably sharp lobes and nulls tend to be formed in the antenna pattern. This increases the criticality of the director positions, and in some cases, requires the use of additional endfire directors for pattern smoothing. In certain cases the 3db omnidirectional pattern may not be possible to attain at all with only two end-fire directors per bay, regardless of the number of plates employed. The employment of large numbers of plates per director and the potential need for more than two directors per bay considerably worsen the problems of supporting the directors and the problems associated with wind load, in addition to increasing the cost of the antenna assembly.

Accordingly, it is an object of the present invention to provide an improved antenna assembly which may employ a low cost, conventional supporting structure, and which obviates or minimizes the aforementioned problems while maintaining a high gain, omnidirectional or other desired antenna pattern, even for supporting structures having extremely large transverse dimensions.

The present invention stems, in part, from the recognition that a more readily controlled or uniform omnidirectional antenna pattern, or a more controlled pattern in general, can be obtained through the use of one or more end-fire parasitic directors when one or more of the normally transverse plates are bent to a substantial angle from normal and have at least a predetermined height transverse to that axis. For example, when the driven elements have horizontal polarization, such as with conventional slot antennas, the bent portion of the plate has a dimension parallel to the plane of the electric field vector ($\bar{E}$) and the bend forms a line which will generally be transverse to the director axis and parallel to the slot and the elongated supporting structure. The bend will thus typically define a vertical line through or somewhat offset from the director axis which generally divides the plate into two lateral portions on opposite sides thereof, one lateral portion defining a plane normal to the director axis and the other lateral portion defining a plane oblique to the director axis at a substantial angle from the normal. The oblique or bent portion in such an assembly is preferably located on the lateral side of the director axis opposite the supporting structure or, in other words, on the "outside" of the assembly.

Moreover, it has been found that for a given diameter (or equivalent dimension) supporting structure, fewer plates on the end-fire directors are required to achieve omnidirectional performance when one or more of the plates of each director are bent in the aforementioned manner. For example, for masts less than one-half wavelength in diameter, one bent plate will typically be sufficient instead of the two spaced flat transverse plates heretofore generally required to provide the omnidirectional pattern. From about one-half to approximately three-quarter wavelength mast diameter, two plates per director will typically produce the omnidirectional pattern with one or both bent as needed, as compared to the requirement of four or more flat plates per director, with the attendant problems previously mentioned.

As the transverse dimension of the mast or other supporting structure increases from one-half wavelength, the bend angle and the height dimension of each plate may be increased to maintain the standard omnidirectional ± 1.5db specification. As the term is herein used, "bend angle" refers to the angle of the plane defined by the bent portion of a conductive plate member measured from a plane which is normal to the longitudinal axis of the director. For omnidirectional antenna performance, it is generally preferable to bend the outside or bent portion toward, rather than away, from the driven antenna element; however, for various directive antenna patterns the bent portion may be bent either toward or away from the driven element.

In all cases, however, the bend angle should be at least approximately 30° from the normal, thus defining generally an angle of between 0 to about 60° between the bent plate portion and the axis of its associated end-fire director. Further, the linear plate dimension in the direction normal to the plane of the nondirective field (typically the electric field or $\bar{E}$ vector) is at least about a third wavelength and preferably from one-half wavelength to the effective length of its associated driven element when a slot or similar type of element is employed.

These and other objects and advantages of the present invention are more particularly set forth in the following detailed description and in the accompanying drawings, of which:

FIG. **1** is a perspective view showing a portion of a section of an antenna assembly in accordance with an embodiment of the present invention;

FIG. **2** is an enlarged, fragmentary, sectional view taken along line **2—2** of FIG. **1**;

FIG. **3** is an enlarged elevational view of an exemplary alternative form of plate element for the endfire parasitic directors employed in accordance with the present invention;

FIG. **4** is a generally diagrammatic plan view of an antenna assembly in accordance with another embodiment of the present invention; and

FIG. **5** is an elevational view of a portion of a section of the antenna assembly of FIG. **4**.

In general, referring to FIGS. **1** and **2**, the antenna assembly in accordance with this embodiment of the invention is especially adapted for transmitting UHF-TV signals of a given wavelength fed thereto from a suitable broadcast transmitter. The assembly generally comprises an elongated conductive supporting structure, illustrated as a vertical tubular mast or pipe section **10**, having a major transverse dimension *d* such as to affect the overall pattern of the antenna assembly, and a plurality of bays, each indicated generally as **12**, which include a driven antenna element **14** carried by the mast **10** and defining a radiation axis **16** extending therefrom. The radiation axis of each driven antenna element is considered herein to be the axis of symmetry of the beam radiated from that element in the direction away from the radiating side of the element and is usually the direction of maximum radiation. A transmission line, illustrated as coaxial cable **18**, is provided for feeding the electrical signals to the driven antenna elements in each of the bays vertically stacked along the mast. At least one, but in most instances two, end-fire parasitic directors, such as **20***a* and **20***b*, are associated with the driven antenna element of a bay, and each director defines a respective longitudinal axis, indicated, for example, as **22** for director **20***a*.

The end-fire directors are so positioned relative to the driven antenna and supporting structure as to alter the shape of the antenna pattern produced by the combined effects of the driven antenna and supporting structure to obtain an omnidirectional or other desired pattern, while not intersecting the radiation axis **16** of the driven antenna.

In the illustrated embodiment of FIG. **1**, the pair of end-fire parasitic directors **20***a* and **20***b* associated with each bay **12** of the antenna assembly have their respective longitudinal axes **22** oriented to intersect, if extended, on the same general side of the antenna assembly as the radiation axis **16** from the driven antenna. The longitudinal axis **22** of each parasitic director preferably lies in a plane which is approximately normal to the longitudinal axis of the supporting structure **10**, and should intersect the supporting structure preferably within a half wavelength of the center of its respectively associated driven antenna, measured along the longitudinal axis of the supporting structure. Desirably, such planes should intersect the supporting structure at the center of each driven antenna, as shown in the illustrated embodiment.

The end-fire director shown in FIG. **2** is representative of all the directors of FIG. **1**, and will be referred to hereinafter for purposes of discussion. Each end-fire director comprises one or more angular or bent conductive members **24** having a first or "inside" planar portion **26** between the director axis **22** and the supporting structure **10** which is transverse to the director axis and a second or "outside" planar portion **28** on the opposite side of the director axis which defines a bend angle θ of at least about 30° from a plane **30** normal to that axis.

These end-fire directors may be considered as a modified type of so-called "plate-on-rod" or "disk-on-rod" structural elements. While such structural elements are discussed in the aforementioned U.S. Pat. No. 3,587,108, showing discrete flat conductive plates disposed in spaced parallel relation along the director axis and being normal thereto, the present end-fire directors have a portion of one or more conductive members normal to the director axis and another portion thereof at a substantial angular relation to the normal, preferably at least 30°. These conductive members, such as **25**, employed for the directors are sometimes hereinafter referred to as "bent plates," since in the preferred embodiments they are readily formed by merely bending a part of the plate element **24** from its transverse orientation (in the plane perpendicular to the director axis) until it forms an acute angle θ of at least about 30°. The particular value of θ will depend on various factors as will be discussed hereinafter.

As shown in the illustrated embodiment of FIGS. **1** and **2**, two plates are employed with each end-fire director, the inner or closer plate **24** (relative to the driven element **14**) is bent, while the outer or further plate **32** is flat. Of course, depending on the diameter d (in wavelengths) of the mast **10** and the desired antenna pattern shape, the further plate **32** might also be bent, or it might be omitted, or additional such plates might be employed spaced apart as taught in the aforementioned patent.

Each of the conductive plates **24** and **32** has a major linear dimension a and b, respectively, in a plane parallel to the plane of the electric field or E vector, being the horizontal dimension in the present embodiment, of between one-quarter and one-half wavelength, regardless of the bend, and preferably about one-third wavelength. The major orthogonal dimension c normal to the plane of the nondirective field ($\bar{E}$) vector, which is the vertical dimension of both plates in the present embodiment, is at least approximately one-third wavelength or greater. The performance or effectiveness of the director in achieving an omnidirectional pattern for the assembly increases as this vertical dimension or height of the conductive plates approaches the length of the slot (or the equivalent dimension of some other type of driven antenna element). Beyond this length, there is no significant increase in effectiveness with respect to the driven element of the associated bay. The length of the slot may generally be from about one-half to just under one wavelength, with two-thirds wavelength being typical.

A suitable interplate spacing range, such as indicated as g and h, is generally between approximately one-eighth and one-half wavelength, with one-fourth wavelength being preferred, and this range also applies to the distance that the transverse portion of the bent plate is from its mounting bracket (i.e., near the driven element).

Turning now more specifically to the particular structures illustrated in FIGS. **1** and **2**, the tubular mast **10** provides support for the antenna assembly, and may be typically formed from standard pipe of hot-dip galvanized structural steel to retard corrosion and to provide strength at low cost. The individual slot type driven antenna elements **14** of the illustrated assembly are (as shown open in the lower bay of FIG. **1**) cut into, or mounted on, the mast **10**. Behind each of the slots is a cavity **34** of the type commonly employed in radiating antennas to form and impedance-match the slots, and the cavities may be merely formed as sheet metal structures. A dielectric cover **35** may be placed over each of the slots as a radome, and may be formed, for example, of glass fibercloth impregnated with a synthetic resin. Each slot of the antenna array is fed a portion of the transmitter power through the transmission line **18** located within the tubular mast **10** and connected in a known manner to the slots for excitation thereof.

Mounted onto the cavities **34**, and thus onto the tubular mast, on either side of each slot antenna are mounting brackets **36** which support the end-fire parasitic directors **20**. The end-fire directors include metal support rods **38** aligned with the longitudinal director axis **22**, and attached to the brackets **36** so that they extend generally outward from the tubular mast **10** on opposite sides of the slot. Then, mounted on each of the support rods **38** are the discrete conductive members **24** and **32**, illustrated in the form of conductive rectangular plates, spaced axially along the rods and having a portion disposed normal thereto. In each bay, the plates closest to the slot are bent plates having their respective outermost portions bent from the normal position towards the slot to form an angle of at least **30** degrees from normal. The other conductive plates of the illustrated embodiment of FIG. **1** have all portions in a common plane normal to the support rod **38**.

At the bottom end of the tubular mast **10** is a flange **40** which may be fastened to another such flange to interconnect two adjacent mast sections for extending the length of the antenna assembly, or which may be fastened to a tower or other base structure, such as by means of suitable bolts or other fasteners through the flange holes shown in FIG. **1**. Suitable coaxial connectors of conventional type may also be provided for interconnecting the various sections of transmission line **18**, as required, and in a well known manner.

In the type of antenna assembly contemplated herein, there is no connection except a structural one, between the elementary driven antennas which transmit electromagnetic radiation and the end-fire directors. That is, the end-fire directors act on the radiating electromagnetic field, but are not necessarily conductively connected to the driven antenna elements. Thus, the brackets **36** could be mounted directly into the tubular mast **10** and need not necessarily be mounted onto the end of the cavity mounting plates as shown. Moreover, it is not, in general, necessary for the directors to be located directly adjacent to the center of their associated elementary antennas in each bay of the antenna assembly. However, as hereinbefore indicated, the axis of each director should preferably lie in a plane which is about normal to the axis of the tubular mast and which intersects the tubular mast within a half wavelength of the center of the respective elementary driven antenna.

Also, if desired, more than one level or set of end-fire directors may be associated with each elementary antenna, and various arrangements may be employed based on the general teachings hereof to obtain particular desired pattern shapes. By varying the particular angle (relative to the radiation axis of the associated driven antenna element), location, and design of the directors, the horizontal or azimuth plane of radiation can be readily controlled to provide the desired antenna pattern.

The use of the bent plate in the manner described herein for the end-fire directors generally permits a reduction in the number of plates required to obtain a given antenna pattern, particularly an omnidirectional one, and provides a pattern which has generally greater regularity and symmetry, without undesirably large or sharp lobes and nulls.

The following particular antenna assembly constructions in accordance with the embodiment of the invention illustrated in FIGS. **1** and **2** have been designed, and performed satisfactory for channels **41, 47** and **57**, respectively, to provide the ± 1.5db omnidirectional specification. The assemblies designed for each of these channels utilized one pair of end-fire directors per bay set at about 40° on each side of the mast (140° from the radiation axis **16**) and two plates per director with only the plate closest to the driven slot antenna element having its outer portion bent towards the slot in the manner illustrated. All of the plates were 12 inches in height ($c = 12$, but could have been made as small as 6 inches in height). The other dimensions common to these assemblies were that the diameter d of the mast **10** was 10¾ inches (O.D.), the width of the cavity mounting plate **42** was 5 inches, the cavity mounting flange or skirt **44** was 3½ inches long, the bracket **36** was angled at 90° and had 2 inch edges, and the metal support rod **38** had a ¾ inch diameter. All of the plates were formed from ⅛ inch thick stock.

These respective antenna assemblies for each of the channels had the following other dimensional parameters (in inches) illustrated in FIG. **2**:

Ch. 41	Ch. 47	Ch. 57
a = 5⅝	a= 5⅝	a = 5
b = 6½	b = 6	b = 5⅝
d = 10¾	d = 10¾	d = 10¾
e = 2⅝	e = 3	e = 2⅝
f = 3	f = 2⅝	f = 2⅝
g = 3⅛	g = 3⅛	g = 2 15/16
h = 4 3/16	h = 3⅞	h = 3¾
i = ⅜	i = ⅜	i = ⅜
$\theta = 45°$	$\theta = 75°$	$\theta = 75°$

For the channel **57** design, where the 10¾ pipe diameter represents two-thirds wavelength, to obtain omnidirectional performance, the plates were required to be as long as the slot (e.g., the 12 inch height represents three-fourths wavelength, which was the slot length) and the bend angle θ could be increased from 75° to almost 90°. Using a bend angle of $\theta = 90°$, omnidirectional performance with a 10¾ inch diameter mast pipe is believed possible up to about channel **60** with similar designs. Larger bend angles are used as the pipe diameter increases in terms of wavelength (or, in other words, as the wavelength decreases for a given diameter) to maintain an omnidirectional pattern, and the bend angle limit is $\theta = 90°$.

Referring now to FIG. **3**, there is shown a modified form of plate, designated **52**, which, instead of being a solid rectangle, has merely the upper and lower edges **54** and **56** respectively, fixed in spacial, separated relationship by a narrow intermediate portion **58**. This modified plate **52**, like those illustrated in the embodiment of FIGS. **1** and **2**, would be fixedly mounted on the director support rods **38** at the center point indicated as **60** in FIG. **3** by any suitable means. With the vertical slot type driven elements previously discussed, which have a horizontal polarization, the plate **52** is disposed with the edges **54** and **56** horizontal. The horizontal edges **54** and **56** are parallel to the plane of the electric field vector, and their linear dimensions are within the ranges previously discussed relative to the solid plates. That is, the major dimension j is between one-fourth and one-half wavelength, and preferably about one-third wavelength. The reduction of solid area in forming the modified plate **52** of FIG. **3** results in a further reduction in the wind load on the antenna assembly, and may be used as a substitute in some applications where this factor is especially important.

The use of conductive plate elements having various surface portions removed is possible because these elements still function as a solid plate with respect to their interaction with the electromagnetic waves being radiated from the antenna. Thus, the term "plate" is used herein in an electrical or electromagnetic wave sense and includes various mechanical structures that affect the wave in the general manner of a plate, but which may actually have the mechanical or physical form of only portions of a solid plate, a mesh or screen, wires or rods, or other conductive elements whose overall effect is to form a generally planar configuration transverse to the director axis, and which may then have a portion thereof bent from the transverse position in accordance with the teachings hereof. Also, such plate structures need not be rectangular, but may be of other shapes, such as disks, etc., as long as they are dimensioned and positioned to achieve the desired results. The plates may also extend continuously, if desired, from each bay to the next, rather than being discrete with respect to each vertically spaced director.

The employment of a pair of directors having single plate elements of the type illustrated in FIG. **3**, but bent to obtain omnidirectional performance from an array of slot elements mounted on a triangular metal openwork tower **62** is depicted in FIGS. **4** and **5**. The tower **62** may be of any conventional construction, and thus the details have been omitted for the sake of clarity. Slots **64** (of which only one is shown) are defined by sheet metal cavities **66** and arranged vertically along one face of the tower by any suitable means, such as by welding or fasteners. The end-fire directors **68** are disposed on opposite lateral edges of the cavity-mounted face of the tower with their respective director axes **70** extending outwardly from the tower as shown.

Each end-fire director **68** comprises a single bent plate **74**, of the edge type generally shown in FIG. **3**, and a metal support rod **76** aligned with the director axis and having a bracket **78** by which the support rod is attached to the tower **62** by any suitable means.

The portion of each bent plate **68** which defines a plane transverse to the director axis **70** comprises two arms or edge strips **80** at the upper and lower ends thereof. The portion of each bent plate **68** which defines a plane oblique to the director axis comprises an-

other two arms or edge strips **82** at the opposite upper and lower ends thereof. The edge strips **82** define a bend angle θ from a plane **84** which is normal to the director axis **70** and coplanar with the strips **80.** The considerations governing the bending, orientation and arrangement of the elements in this embodiment are generally the same as hereinbefore discussed in connection with the embodiment of FIGS. **1** and **2,** and thus will not be repeated.

The following will provide an example of typical dimensional parameters (in inches) for an antenna assembly of the type illustrated in FIGS. **4** and **5** for channel **5** broadcasting to provide omnidirectional performance, wherein the tower **62** has approximately 63 inch sides, indicated by the transverse dimension *k* in FIG. **4** (at channel 5 frequencies, one wavelength is approximately 12½ feet):

Ch. 5
l = 51½
m = 32¼
n = 25⅞
p = 29¼
q = 17¼
r = 39
s = 14¼
t = 96
θ = 30°

In the above example, the angle between the support rods **76** and their respectively adjacent tower side is 84°, and the support rods were 3 inches in diameter but may be varied to a smaller diameter consistent with their ability to provide the required support. Each cavity **66** was 93 inches high, but this dimension may vary. Also, tubular arms rather than the flat edge strips may alternatively be employed.

In another example, the pair of end-fire directors in each bay had edge type plate elements of the type illustrated in FIG. **3** and were used on a broadcast antenna assembly for operation at channel 9 (one wavelength being about 62½ inches) to provide omnidirectional performance from a 14 inch (O.D.) mast. Each director employed only one bent plate wherein the linear horizontal dimension *j* was 22 inches with the bent portion extending 9½ inches from its lateral end and defining a bend angle of 45°. Each plate was spaced **15 3/4** inches from its mounting bracket on a 2 inch diameter support rod, and was 24 inches in height.

Although in the illustrated antenna assemblies, the driven antenna element which is used as a launcher is a slot, it is understood that any driven type of element could be used, including (but not limited to) a dipole, Vee, loop or short helix. Also, it is understood that although the plate elements in the illustrated embodiment are supported on metallic support rods, other means, including insulators, for supporting the conductive plates may be employed.

The final design of an antenna assembly for any particular application in accordance with the principles of the present invention is determined readily by routine design techniques and simple experiment, applying the teachings hereof.

Although the exact manner of operation of the present invention is not yet completely understood in detail, it is believed that the bent portions of the director plates produce a fanning or smearing of the radiated electromagnetic wave phase centers and thus prevent direct addition of the wavefronts. Also, it is believed that the same amount of energy is captured by the bent plate directors as with the flat plate directors, all other parameters being equal, and the smoothing of the pattern does not result from any fanning or spread in amplitude, but in the fanning or distribution of the phase of the captured radiation about the mast.

Additionally, it should be noted that the maximum bend angle is 90°, i.e., where the bent portion of the plate is about parallel with the director axis, and this angle generally produces the maximum effect. This effect would not be produced if the bent portion were removed. Bend angles which are substantially smaller than 30°, such as under 15° or so, are not at all effective in employing the principles of the present invention and are considered to define essentially flat plates. For best design in achieving omnidirectional performance the bent portion of each plate should define an acute angle with the director axis that faces in the same general direction or side of the assembly as the driven element and its radiation axis.

Also, the teachings of copending application Ser. No. 118,436, filed Feb. 24, 1971, and now U.S. Pat. No. 3,718,934 of the same inventor, are applicable to the antenna assemblies of the present invention to provide interlaced antenna arrays on a common supporting structure which perform almost independently with very little coupling or interaction despite their proximity.

The embodiments of the invention illustrated in the drawings and described above will suggest to persons skilled in the art a number of variations and modifications, some being immediately obvious and others obvious upon study from the basic teachings of the invention. Although such variations and modifications may result in structures which are mechanically different in appearance, they may embody the principles of the invention. Therefore, the scope of the protection to be afforded the invention should not be limited by the particular embodiments shown and described, but should be defined by the appended claims, and equivalents thereof.

Various features of the invention are set forth in the following claims.

What is claimed is:

1. An antenna assembly for transmitting signals of a given wavelength, comprising an elongated electrically conductive supporting structure having a major transverse dimension such as to affect the pattern of the antenna assembly, a driven antenna element carried by said supporting structure and defining a radiation axis extending therefrom, and at least one end-fire parasitic director having an axis extending generally from said structure and comprising a conductive member having a first planar portion on one side of said axis being transverse thereto and a second planar portion on the opposite side of said axis defining an angle of at least about 30° from the normal thereto, said director being so positioned relative to said driven antenna and supporting structure as to alter the shape of the antenna pattern produced by the combined effects of said driven antenna and supporting structure, while not intersecting the radiation axis of said driven element, to provide a selected pattern for said antenna assembly.

2. The antenna assembly of claim **1** wherein said first and second planar portions of said conductive member have a combined linear dimension in a plane parallel to

the plane of the nondirectional field produced by said driven element of between approximately one-fourth and one-half wavelength.

3. The antenna assembly of claim **2** wherein said combined linear dimension is approximately one-third wavelength.

4. The antenna assembly of claim **2** wherein said conductive member has a linear dimension normal to the plane of the nondirectional field produced by said driven element of at least approximately one-third wavelength.

5. The antenna assembly of claim **1** wherein said first planar portion of said conductive member is located between said director axis and said supporting structure, and said second planar portion is located on the outside of said assembly.

6. The antenna assembly of claim **5** wherein said second planar portion defines an acute angle with said director axis and said acute angle faces the same general side of the assembly as said radiation axis.

7. The antenna assembly of claim **1** wherein said end-fire director comprises another conductive member having a portion thereof transverse to said director axis and spaced therealong from said first mentioned conductive member a distance approximately from one-eighth to one-half wavelength.

8. The antenna assembly of claim **7** wherein said distance is approximately one-fourth wavelength.

9. The antenna assembly of claim **1** further comprising another end-fire director like said first mentioned end-fire director, wherein each of said directors is mounted to said elongated supporting structure on opposite sides of said driven element with their respective axes defining a plane approximately normal to the longitudinal axis of said structure and intersecting said longitudinal axis within one-half wavelength of the center of said driven element.

10. An antenna assembly for transmitting signals of a given wavelength, comprising a vertical elongated electrically conductive supporting structure having a transverse dimension of at least approximately one-fourth wavelength, at least one bay including a driven antenna element carried by said structure for producing radiation of horizontal polarization and defining a radiation axis extending from said element, means for feeding electrical energy signals to said driven antenna element, and a pair of end-fire parasitic directors having their respective axes extending generally horizontally from said driven element, each of said directors comprising a conductive member having a linear dimension in a plane parallel to the plane of the electric field vector of the transmitted signal of approximately one-fourth to one-half wavelength, said conductive member comprising a first planar portion between the director axis and said structure being transverse to said director axis and a second planar portion on the opposite side of the director axis defining an angle of at least about 30° from the normal thereto, said conductive member having a vertical dimension of at least approximately one-third wavelength, said director being so positioned relative to said driven antenna and supporting structure as to alter the shape of the antenna pattern produced by the combined effects of said driven antenna and supporting structure, while not intersecting said radiation axis, to provide a selected pattern for said antenna assembly.

11. The antenna assembly of claim **10** wherein said first and second planar portions of said conductive member each comprise a pair of separated conductive parts in planes parallel to the electric field vector and respectively defining the plane of each of said planar portions.

12. The antenna assembly of claim **10** wherein said conductive member is formed by a bent plate with the first planar portion of the plate being transverse to the director axis and the second planar portion of the plate being bent toward said driven element.

13. The antenna assembly of claim **10** wherein said end-fire directors each comprise another conductive member having a portion thereof transverse to said director axis and spaced therealong from said first mentioned conductive member a distance approximately from one-eighth to one-half wavelength.

14. The antenna assembly of claim **10** wherein said directors are mounted to said vertical supporting structure with their respective axes defining an approximately horizontal plane intersecting said structure within one-half wavelength of the center of said driven element.

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