United States Patent [19]

Truskanov et al.

[11] **3,829,864**

[45] **Aug. 13, 1974**

[54] **TRANSMITTING STACKED AERIAL**

[76] Inventors: **David Matveevich Truskanov,** ulitsa Ostroumova, 10, kv. 35; **Kirill Rudolfovich Brunin,** Nalichnaya ulitsa, 33, kv. 13; **Lev Semenovich Ratner,** prospekt Morisa Toresa, 30, kv. 37, all of Leningrad, U.S.S.R.

[22] Filed: **Oct. 15, 1973**

[21] Appl. No.: **406,615**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 380,227, July 18, 1973, abandoned, which is a continuation of Ser. No. 264,407, June 15, 1972, abandoned, which is a continuation of Ser. No. 40,960, May 27, 1970, abandoned.

[52] **U.S. Cl.** **343/833,** 343/853, 343/890

[51] **Int. Cl.** **H01q 21/00**

[58] **Field of Search** 343/796, 797, 798, 799, 343/800, 844, 890, 891

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

544,401 1/1956 Italy 343/800

Primary Examiner—Eli Lieberman

Attorney, Agent, or Firm—Holman & Stern

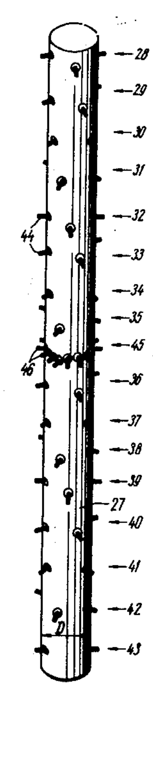
[57] **ABSTRACT**

A transmitting stacked aerial comprising a current-conducting cylindrical support and tiers comprising current-energized radiators. In each tier, radiators are arranged equidistantly along at least some portion of the periphery of the cross-section of the support and are radially oriented relative to the surface thereof. Radiators in each tier are offset in azimuth relative to those of each next tier through a preset angle and are energized with currents of an equal phase, consecutively shifted by 90° from tier to tier. Radiators in each tier are offset in aximuth relative to those in each next tier through an angle of $\psi/4$ (ψ being an angle between adjacent radiators in the same tier). The angle ψ is less than an angle $\beta=[(2\lambda o/D)\cdot 57.3]°$, where D is a diameter of the support and λ is the mid-band wavelength. Radiators in each tier are consecutively offset in azimuth relative to those in the next tier through said angle of $\psi/4$. The radiators are energized with currents of an equal phase, consecutively shifted in one direction by 90° from tier to tier.

In another embodiment, a transmitting stacked aerial also comprises an additional tier of radiators arranged in the middle of the radiating portion of the aerial. This additional tier is designed to rule out troughs in the radiation pattern of the aerial in the vertical plane and is arranged symmetrically with respect to the first and last tiers. Additional radiators are arranged equidistantly along the periphery of the cross-section of the aerial support, with an angle Σ between adjacent additional radiators being less than an angle $\gamma=[(\lambda 0/2D\cdot 57.3]°$.

Additional radiators are energized with currents of an equal phase, shifted by an angle of 90°, through four radiators. All concerning the second embodiment only holds true with an even number of main tiers.

8 Claims, 16 Drawing Figures



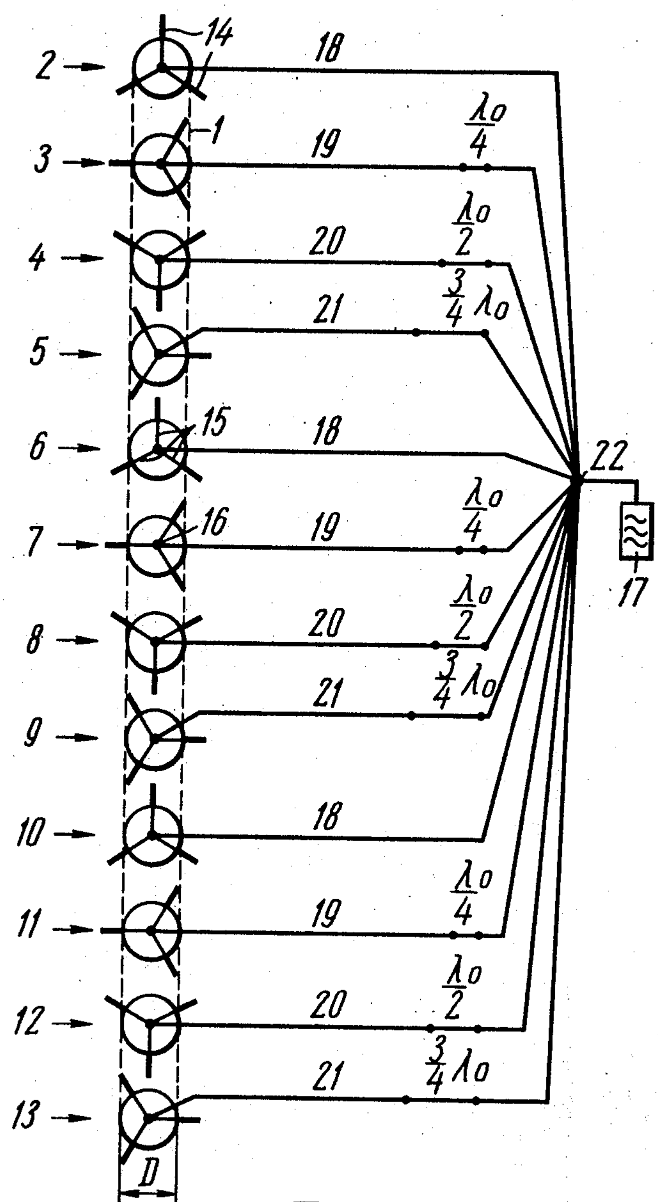


FIG. 1

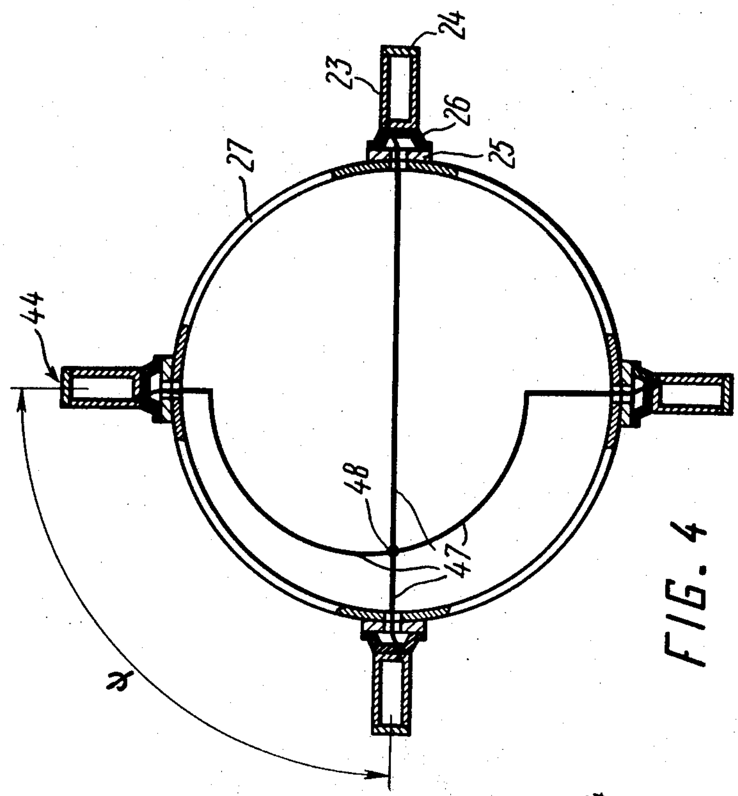


FIG. 4

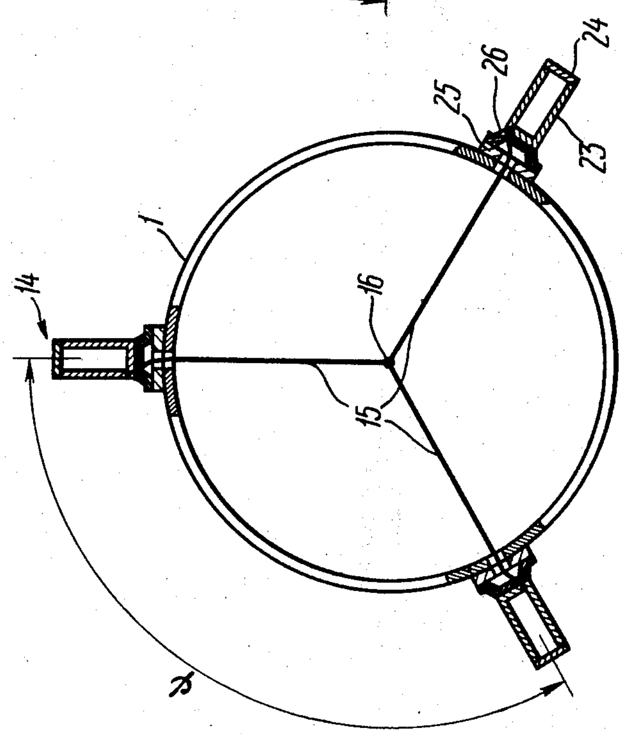
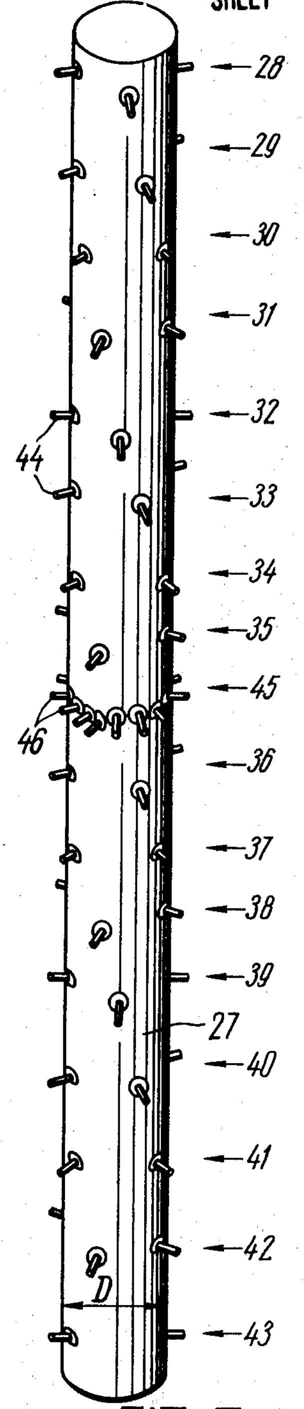


FIG. 2


28
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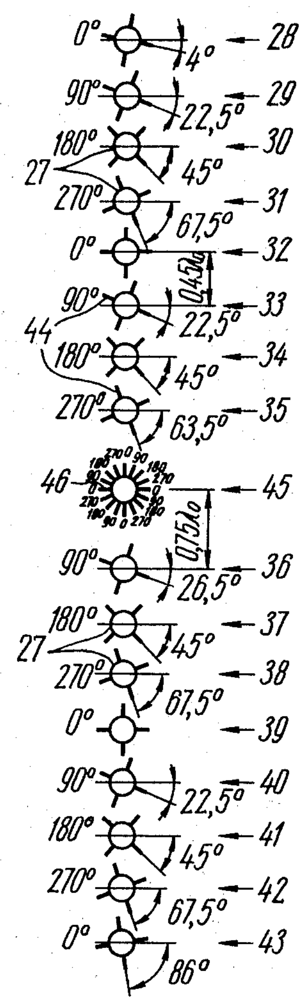
D

FIG. 3


0°
4°
28
90°
22,5°
29
180°
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30
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270°
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90°
22,5°
33
44
180°
45°
34
270°
63,5°
35
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45
0,75λo
90°
26,5°
36
180°
45°
37
27
270°
67,5°
38
0°
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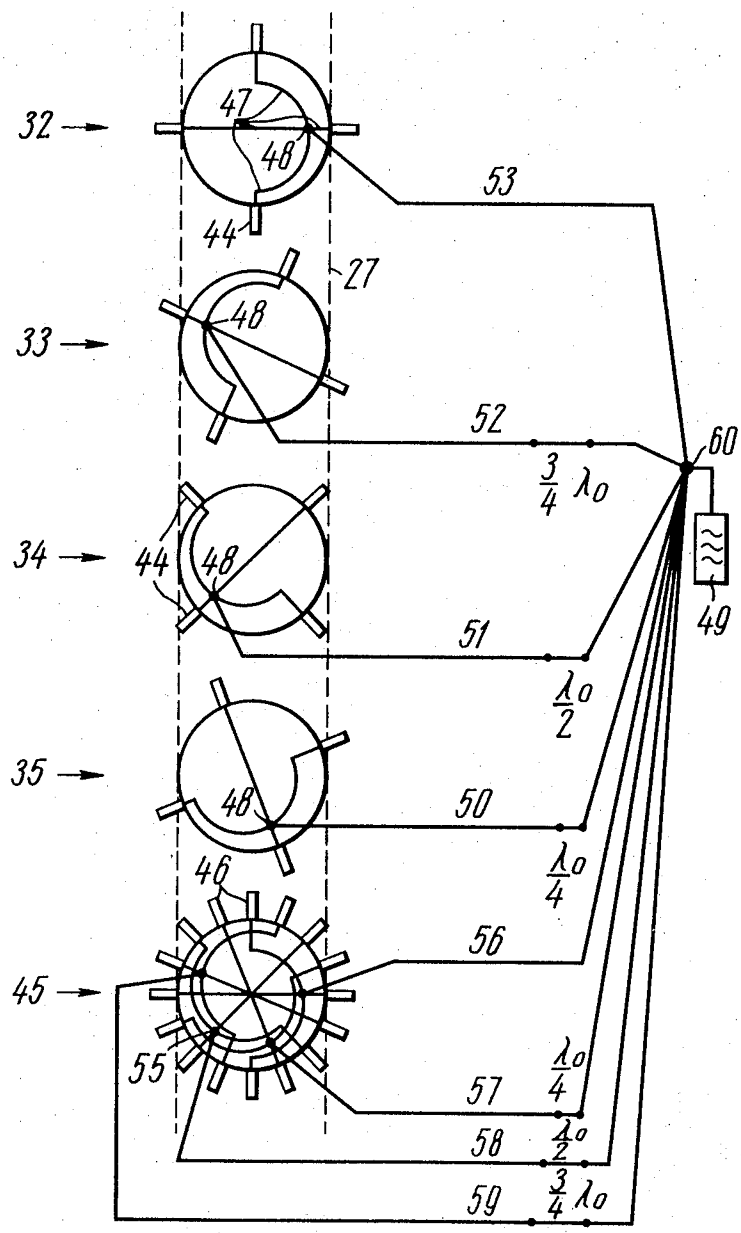
22,5°
40
180°
45°
41
270°
67,5°
42
0°
86°
43

FIG. 5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47
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$\frac{3}{4}\lambda_0$
34
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$\frac{3}{4}\lambda_0$

FIG. 6

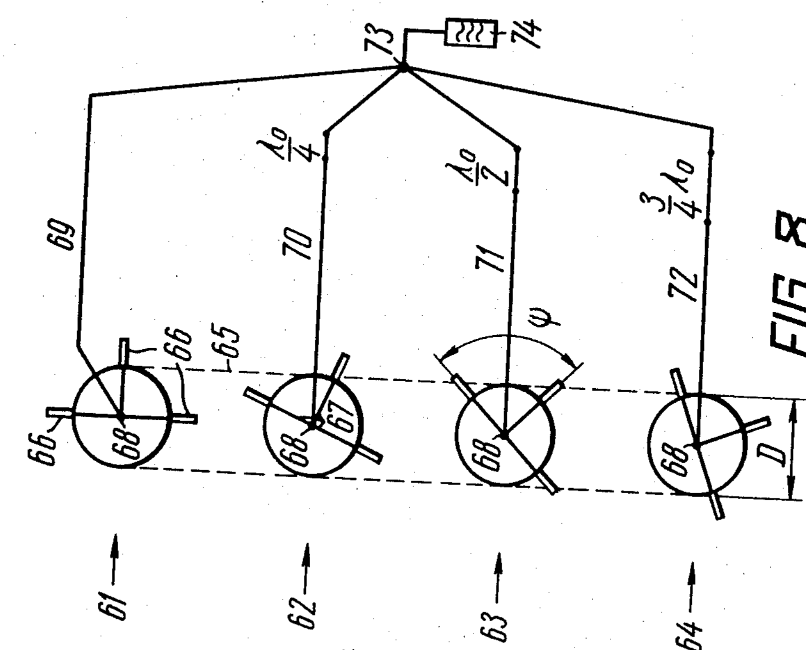
73
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FIG. 8

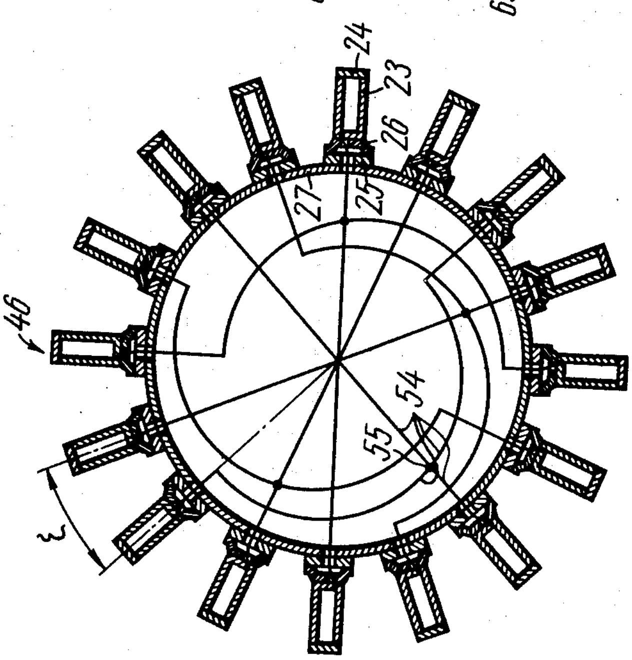
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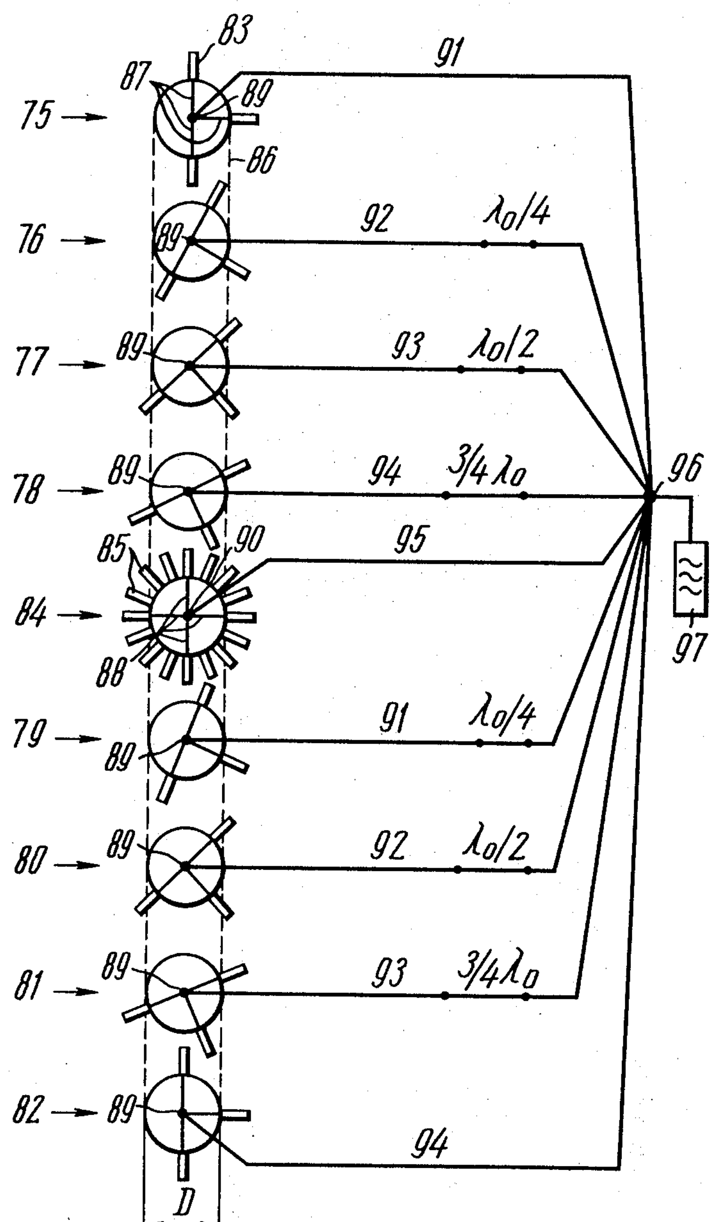
FIG. 7


83
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$\lambda_0/4$
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$3/4\lambda_0$
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FIG. 9

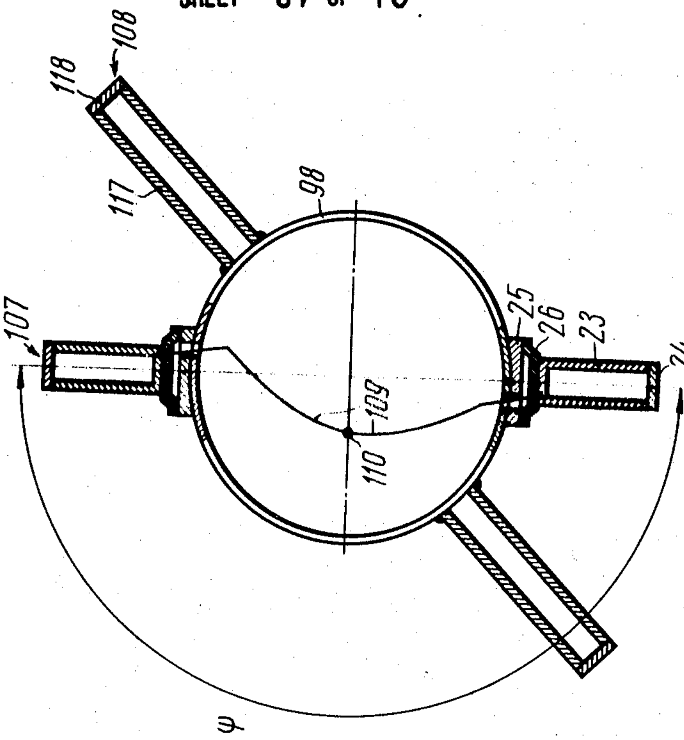
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FIG. 11

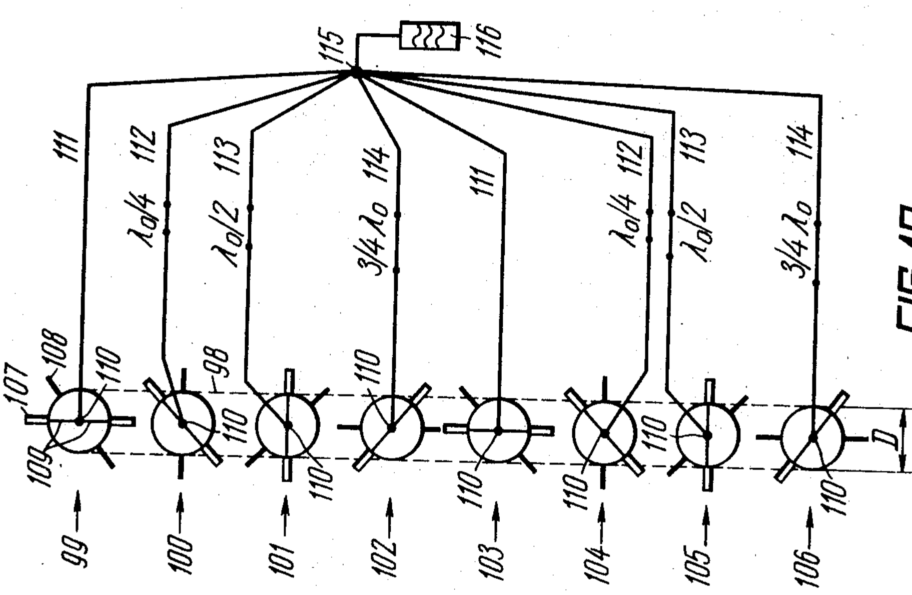
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FIG. 10

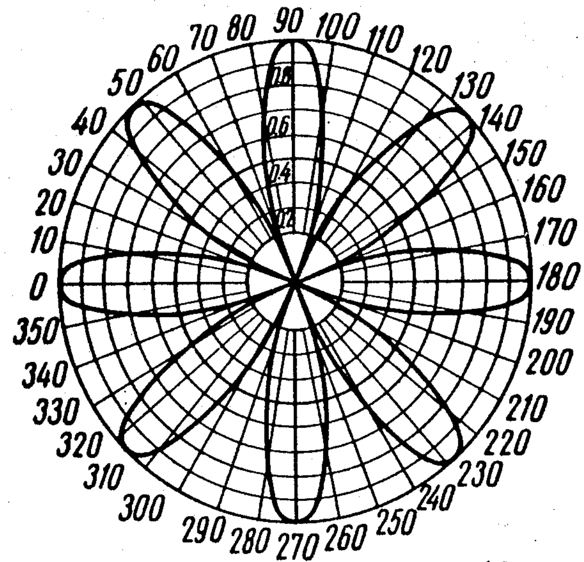
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FIG. 12

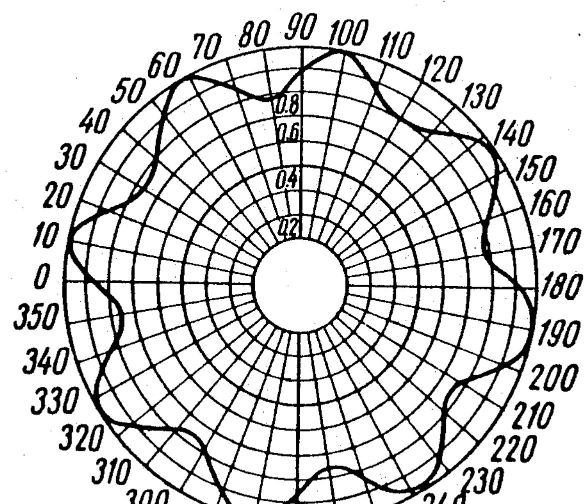
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FIG. 14

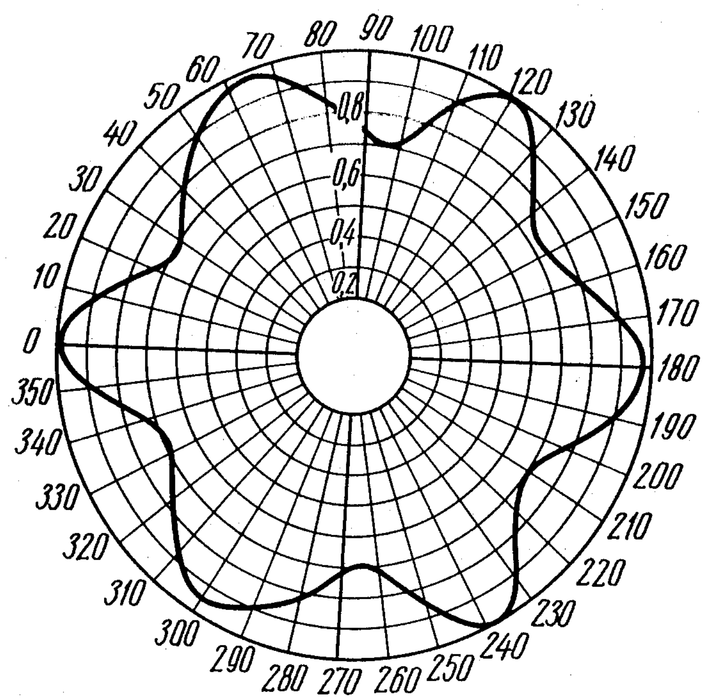
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FIG. 13

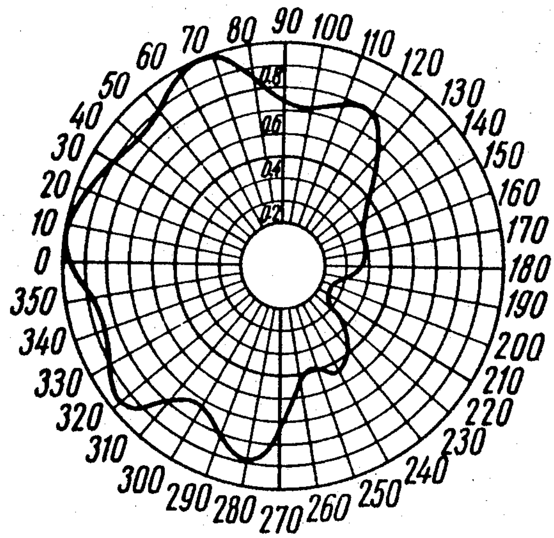
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FIG. 15

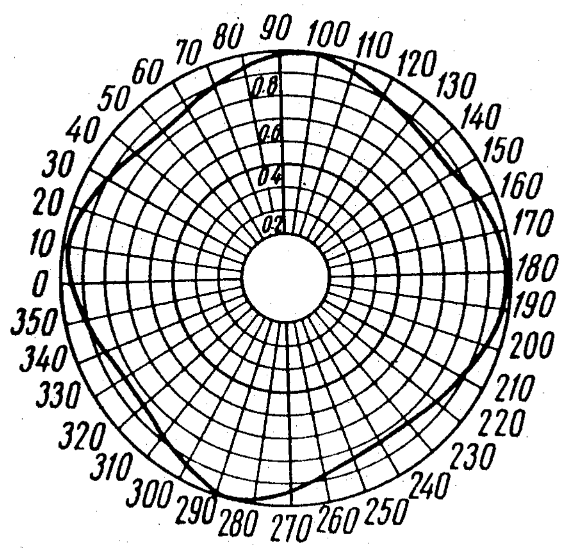
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FIG. 16

TRANSMITTING STACKED AERIAL

The present application is a continuation-in-Part of our co-pending application, Ser. No. 380,227 filed July 18, 1973 which, in turn, is a continuation of application, Ser. No. 264,407 filed June 15, 1972, which application, in turn, is a continuation of application, Ser. No. 40,960 filed on May 27, 1970. All prior applications are now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to aerials and more particularly to transmitting stacked aerials used for TV and VHF-FM broadcasts.

Known are recently developed transmitting TV aerials with horizontal-tangential radiators arranged around the aerial support (cf. U.S. Pat. No. 3,329,959). In such aerials, radiators are adjusted through changing the geometry thereof (the length, diameter and the shape of radiators' end face surfaces) and through changing a distance between a radiator and the support (reflector). This, however, changes the radiator's partial pattern, which accounts for a non-uniform radiation pattern of the aerial as a whole. It should also be taken into consideration that in order to obtain a negligibly non-uniform radiation pattern in the horizontal plane with supports of different cross-sections, use has to be made of radiators with a diffent partial pattern width.

As a result, it is very difficult, using horizontal-tangential radiators, to obtain a high degree of adjustment of radiators with the power line in combination with a negligible degree of non-uniformity of the radiation pattern of the aerial. Even if this result is obtained with a certain cross-section (diameter) of the support, it is no longer the case with another cross-section (diameter).

In order to make the horizontal plane radiation pattern less non-uniform, in some stacked aerials radiators of adjacent tiers are displaced relative to one another by a certain angle. This applies, for example, to aerials described in Italian Pat. Nos. 527,649 and 544,401, in British Pat. No. 936,029 and in FRG Pat. No. 1,147,993.

Aerials built in accordance with the above patents are marked by the following distinguishing features:

adjacent tiers are turned with respect to one another through a certain angle, said angle of the turn of the adjacent tiers being equal to ($\psi/2$, where ψ is an angle between adjacent radiators in the same tier;

radiators in each tier are energized according to the rotating field principle, the phase of currents being displaced from tier to tier by an angle equal to that between radiators in a tier;

radiators in adjacent tiers are energized with the current phase being displaced at a certain angle, said phase displacement angle of currents energizing radiators of adjacent tiers being equal to that of their offest in azimuth, i.e. it is equal to $\psi/2$;

The direction of said turn of tiers changes consecutively from tier to tier to the opposite, so that in each other tier the arrangement of radiators is repeated;

The direction of said current phase displacement of radiators in adjacent tiers changes to the opposite from tier to tier, so that in each other tier the phases of the radiators' currents are repeated;

a preferred angle between radiators in a tier is determined irrespective of the ratio (D/ψ_o).

Aerials built according to cited patents employ supports of small cross-sections, when the perimeter of the cross-section of the support is less that the wavelength and when it may be assumed that said energizing of radiators in each tier with currents of reverse phases according to the rotating field principle ensures alteration of the phase of the field according to the linear law, with the phase characteristic slope equal to unity.

In a number of instances, the use of aerials of the above type does not lead to the desired effect, for example, when an aerial is mounted upon a support with a large cross-section, whose perimeter is either equal to or even exceeds the wavelength.

Further development of aerial engineering has led to the development of a transmitting stacked aerial with radiators mounted upon the support and radially oriented with respect to its surface (cf. USSR Inventor's Certificate No. 240,047). In such aerials, radiators in each tier are divided into two groups so that radiators of one group are arranged between those of the other group and are energized, within each group, from a power source with currents of an equal amplitude and phase. The difference between the phases of the currents energizing the above groups is that of an angle of 90°.

The radiation pattern of each group practically does not depend upon the geometry of a radiator, including its length, the shape of its face end surfaces and the width of a clearance between the radiator and the support. When radiators are energized with cophasal currents and are arranged equidistantly around the support, the radiation pattern of the group is determined by the ratio (D/ψ_o) and by a number of radiators in a group.

Hence, when adjusting radiators to the power line by way of changing their geometry, one need not take into consideration the form of the radiation pattern of the group; in this respect, aerials of this type compare favorably with those with horizontal-tangential radiators.

Unlike aerials with horizontal-tangential radiators, aerials with radially oriented radiators may have a radiation pattern in the horizontal plane extremely close to an ideal circle, provided that there is a required number of radiators in the groups and that these are energized in the above-mentioned manner with currents of equal amplitudes, the phases of the currents energizing different groups being displaced by an angle of 90°.

It is difficult, however, to obtain a non-directional radiation pattern in the horizontal plane with the use of such aerials because of inter-coupling between radiators of different groups which are arranged close to each other and are energized with non-cophasal currents; this accounts for a difference between their input impedances. As a result, the power is divided between the radiator groups in an unforseen manner, adjustment of the aerial is hampered, and its electrical characteristics are impaired in comparison with the estimated ones.

It is an object of the present invention to provide a transmitting stacked aerial with radially oriented radiators, in which inter-coupling between adjacent radiators in neighboring tiers, which are energized with non-cophasal currents, is obviated by arranging the radiators around the support and energizing them in such a way that the emfs induced in a given radiator by said currents in radiators of the neighboring tiers are mutually cancelled.

Another object of the present invention is to provide a transmitting stacked aerial capable of eliminating troughs in its vertical plane radiation pattern.

In view of the above objects, in a transmitting stacked aerial, thereof each main tier comprises a preset number of radiators energized from a power source, mounted upon a current-conducting cylindrical support and radially oriented with regard to its surface, the radiators being energized with currents displaced in phase by 90° from tier to tier, the radiators in each tier are arranged, according to the invention, equidistantly along at least some portion of the periphery of the cross-section of the support and are offset in azimuth relative to the respective radiators of an adjacent tier by a preset angle equal to ($\psi/4$), where ψ is an angle between adjacent radiators in a tier, which is less than an angle $\beta=[(2\lambda_o/D) . 57.3]^o$, where D is a diameter of the support, and λ_o is the mid-band wavelength, the radiators being turned in one direction from tier to tier and being inter-connected by means of radio frequency lines of an equal length to one point of connection, due to which radiators in each tier are energized with cophasal currents, said displacement in phase being effected from tier to tier in consecutive order in one direction.

Mounting an aerial upon supports rising high above the Earth's surface brings about the necessity of eliminating troughs in the vertical plane radiation pattern thereof. This may be attaned by providing the proposed aerial with an additional tier of additional radiators, keeping the number of main tiers even. Said additional tier is arranged in the middle of the radiating portion of the aerial symmetrically to the first and last main tiers. This additional tier has a non-directional radiation pattern in the horizontal plane. Troughs in the vertical plane radiation pattern are eliminated by means of introducing a phase difference between the radiation field of the additional tier with respect to that of all the main tiers. In this additional tier, radiators are arranged equidistantly along the periphery of the cross-section of the support and are radially oriented relative to its surface, an angle Σ between adjacent additional radiators being somewhat less than an angle $\gamma=(\lambda_o/2\ D)$, the radiators themselves, which are offset in azimuth with respect to one another by an angle of 4 Σ, being electrically connected by means of radio frequency lines to one point of connection, due to which these radiators are energized with cophasal currents, the power source being connected to points of connection of the additional tier in such a way that it ensures a displacement in phase of the currents energizing adjacent additional radiators in the additional tier by an angle of 90°, said displacement in phase being effected in consecutive order from radiator to radiator so that the direction of this displacement in phase from radiator to radiator in the additional tier in the chosen direction of the turn of adjacent main tiers coincides with that of the phase displacement of radiators in the main tiers, following the course of the turn thereof from one main tier to another.

In order to obtain a circular radiation pattern in the horizontal plane, a preset portion of the periphery of the cross-section of the support may be determined by the entire periphery of the cross-section of the support and be equal to 360°.

In some cases, when each tier of the aerial comprises a limited number of radiators, it may be necessary to improve its partial radiation pattern so as to reduce the non-uniformity of the radiation characteristic of the entire aerial.

For this purpose, passive dipoles are arranged in each main tier of the proposed aerial in immediate proximity to the radiators thereof; the number of the passive dipoles is equal to that of the radiators; they are mounted upon the aerial's support and are radially oriented relative to the surface thereof.

In all the embodiments of the aerial disclosed herein, the emfs induced in any given radiator of a given main tier, which is not the first or last, by currents of radiators of adjacent main thiers are cancelled because the currents energizing them are in anti-phase. As a result, the input impedances of radiators of the main tiers are equal and the power fed to the aerial is divided among them in equal amounts. In addition, the elimination of the effect of intercoupling between radiators of adjacent tiers ensures feeding of the aerial's radiators in accordance with a required current distribution, which makes it possible to obtain the aerial characteristics that are very close to the estimated.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in greater detail with reference to the specific embodiments thereof in the form of directional and non-directional aerials, taken in conjunction with the accompanying drawings, wherein;

FIG. 1 is a plan view of tiers with radiators of a transmitting stacked aerial, in accordance with the invention, together with a power source;

FIG. 2 is a plan view of one of the aerial's tiers with radiators of FIG. 1 with a cross-section of the support;

FIG. 3 is a general view of the radiating portion of another embodiment of the proposed transmitting stacked aerial;

FIG. 4 is a plan view of one of the aerial's tiers with radiators of FIG. 3 with a cross-section of the support;

FIG. 5 is a plan view of the serial's tiers of FIG. 3 and of the phase of the current energizing them;

FIG. 6 is a plan view of several of the aerial's tiers with radiators of FIG. 3 with a power source;

FIG. 7 is a view of additional tier of additional radiators of the aerial of FIG. 3 with a cross-section of the support;

FIG. 8 is a plan view of tiers with radiators of a transmitting stacked aerial, in accordance with the invention, having a directional radiation pattern, together with a power source;

FIG. 9 is a plan view of main tiers with radiators and of an additional tier with additional radiators of a transmitting stacked aerial, in accordance with the invention, with a power source;

FIG. 10 is a plan view of tiers of the proposed aerial with radiators and passive dipoles in the tiers;

FIG. 11 is a plan view of one tier of the aerial of FIG. 10 with part of the cross-section of the support;

FIG. 12 is a radiation pattern in the horizontal plane of a main tier of the aerial of FIGS. 1 and 3;

FIG. 13 is a radiation pattern of the aerial of FIG. 1;

FIG. 14 is a radiation pattern of the aerial of FIG. 3;

FIG. 15 is a radiation pattern of the aerial of FIG. 8;

FIG. 16 is a radiation pattern of the aerial of FIG. 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An example of a non-directional TV aerial, according to the present invention, is offered by an aerial for TV Band II (76 – 100 MHz).

According to the invention, the aerial is arranged around a current-conducting cylindrical support **1** (FIG. **1**) with a diameter $D = 0.7\ \lambda_o$ (λ_o being the mid-band wavelength) and comprises twelve tiers **2** through **13** of radiators **14** (three in each tier) mounted upon the support **1** and radially oriented relative to the surface thereof. Here, as in all other embodiments, tiers are counted from the uppermost one down. A number of radiators in a tier is determined specifically for each individual embodiment, depending upon a ratio between a perimeter of the aerial's support and the wavelength, as well as limitations imposed upon the nonuniformity of the radiation pattern.

In the general case, the cross-section area of the support may be sufficiently large, so as to secure the required stiffness of the structure as a whole, on the one hand, and to accommodate, if necessary, all the feed-line elements, ladders and lifts inside it, on the other. The arrangement of the above-listed components and units of the aerial structure inside the support substantially facilitates servicing and improves the reliability of the structure.

In each tier **2** through **13**, the radiators **14** are arranged equidistantly, at least within part of the periphery of the cross-section of the support **1.** In the present embodiment, these are arranged throughout the entire periphery, i.e. cover 360°. Radiators in each tier **2** through **13** are offset in azimuth relative to respective radiators of an adjacent tier by an angle ($\psi/4$), where ψ (FIG. **2**) is an angle between adjacent radiators **14** of the same tier. Said angle **104** is less than an angle $\beta = [(2\ \lambda_o/D)\ .\ 57.3]^o$; in the present embodiment, the angle $\beta = 160°$, and the angle ψ is chosen to be equal to 120°.

The tiers **2** through **13** (FIG. **1**) are consecutively turned in one direction with respect to one another. In the present embodiment, each lower tier is turned clockwise with respect to the upper one, if we take a top view of the aerial. The radiators **14** of each tier **2** through **13** are electrically interconnected by radio frequency lines **15** of an equal length to one point of connection **16**; as a result, radiators in each tier are energized with cophasal currents. Said points of connection **16** are electrically coupled to a power source **17** of the radiators **14** by radio frequency lines **18** through **21** which are connected to the power source **17** at an outlet **22.**

The present disclosure does not deal with adjustment units arranged at points of connection **22** and **16,** which adjust the radio frequency lines **18** through **21** with the power source **17,** on the one hand, and with the radio frequency lines **15,** on the other, as said adjusting units have no bearing upon the present invention and are well known to those in the art.

The same applies to a description of the method of running and connecting radio frequency lines. In the present example, these lines differ in their electric length by $\lambda_o/4$, $\lambda_o/2$ and $3/4\lambda_o$, respectively, thereby the phase of the currents energizing radiators **14** of adjacent tiers is consecutively changed by 90° in one direction. Said phase displacement of currents energizing radiators of adjacent tiers may be obtained in the aerial of FIG. **1** not only due to the employment of radio frequency lines of a different length, but also as a result of using other known phase shifters.

The radiator **14** (FIG. **2**) is an assymmetrical band quarter-wave dipole made as a hollow metal cylinder **23** whose outer face end is covered by a lid **24** and which is fastened to the support **1** by means of a metal flange **25** and an insulator **26.** The insulator **26** serves to protect it from atmospheric precipitation. Instead of the above radiator, the aerial may employ, according to FIG. **1** and **2,** other known asymmetrical radiators (monopoles).

An example of the proposed aerial with an additional tier of additional radiators for non-directional radiation is furnished by an aerial for TV Band III (174–230 MHz).

The aerial is arranged around a cylindrical current-conducting support **27** (FIG. **3**) with a diameter $D = 1.17\ \lambda^o$ and comprises an even number, in the present example, 16, main tiers **28** through **43** of radiators **44** (four in each tier) and one additional tier **45** of additional radiators **46.** The angle $\beta = [(2\lambda_o/D)\ .\ 57.3]\ ^o = 98°$. The angle ψ (FIG. **4**) between adjacent radiators **44** in each main tier **28** through **43** is to be less than the angle β. In the present example, $\psi = 90°$, and said radiators in the main tiers are arranged equidistantly around the entire periphery of the cross-section of the support, i.e. cover 360°.

The radiators **44** (FIG. **5**) of each main tier **28** through **43** are offset in azimuth relative to respective radiators in adjacent tiers by an angle ($\psi/4$). In our example, $(\psi/4) = 22.5°$. The radiators **44** (FIG. **6**) of each main tier **28** through **43** (FIG. **3**) are electrically interconnected by first radio frequency lines **47** (FIG. **6**) of an equal length to one point of connection **48,** which makes for energizing the radiators in each main tier with cophasal currents.

Said points of connection **48** are electrically connected to a power source **49** through radio frequency lines **50** through **53.** In the present example, these lines differ in their electrical length by $\lambda_o/4$, $\lambda_o/2$ and $3/4\lambda_o$, respectively, thereby the phase of the currents energizing radiators of adjacent tiers is displaced from tier to tier by 90° in one direction.

As it has been stated above, in order to fill troughs in the radiation pattern of the aerial in the vertical plane, provision is made for an additional tier **45** of additional radiators **46,** which is arranged in the middle of the radiating portion of the aerial symmetrically with the first tier **28** (FIGS. **3** and **5**) and the last tier **43.** The additional radiators **46** (FIG. **7**) are arranged equidistantly along the periphery of the cross-section of the support **27** and are radially oriented relative to the surface thereof. An angle Σ between adjacent additional radiators **46** also is to be less than an angle $\gamma = [(2\lambda_o)/D \cdot 57.3]°$, and with an equidistant arrangement of the radiators **44** (FIG. **5**) along the entire periphery of the cross-section of the support **27**, this angle γ is four times less than the angle ψ between adjacent radiators

44. In the present example, $\Sigma = 22.5°$. The additional radiators **46**, which are offset in azimuth relative to one another by an angle 4Σ, are electrically interconnected by second radio frequency lines **54** of an equal length to one point of connection **55**, thereby these radiators are energized with cophasal currents. Said points of connection **55** (FIG. **6**) are electrically connected to the power source **49** by radio frequency lines **56** through **59** at a point of connection **60**. Also connected to said point of connection **60** are the radio frequency lines **50** through **53**. In the present example, the radio frequency lines **56** through **59** differ in their electrical length by $\lambda_o/4$, $\lambda_o/2$ and $3/4\lambda_o$. Thus, the currents energizing adjacent additional radiators **46** (FIG. **5**) of the additional tier **45** are displaced in phase by 90°, said phase displacement being effected in consecutive order from radiator to radiator so that the direction of the phase displacement from radiator to radiator of the additional tier **45** follows the chosen direction of the turn of the main tiers **28** through **43** and coincides with that of the phase displacement of the currents energizing radiators **44** from tier to tier following the turn thereof.

The required phase displacement of the radiation field of the additional tier **46** with respect to the radiation field produced by all the main tiers **28** through **43** is attained due to the fact that electrical lengths of the radio frequency lines **50** through **53** (FIG. **6**) differ in the present example from respective lengths of the radio frequency lines **56** through **59** by $\lambda_o/12$.

Said required phase displacements of currents energizing the radiators **44** and the additional radiators **46** may be obtained not only due to the employment of radio frequency lines of different lengths, but also through using other known phase shifters.

The radiator **44** (FIG. **4**) and the additional radiator **46** (FIG. **7**) are made in an analogous manner as the radiator **14** (FIG. **2**), i.e., as the hollow metal cylinder **23** (FIGS. **4** and **7**) with the lid **24**, which is fastened to the support **27** by means of the metal flange **25** and the insulator **26**.

A distance between the main tiers **28** through **43** is selected depending upon requirements imposed upon the radiation pattern of the aerial in the vertical plane, taking into account the ratio (D/λ_o) and the number of the main radiators **44** in each tier. As regards the aerial in question, in it said distance between the main tiers **28** through **43** is roughly equal to $0.45\ \lambda_o$. The distance between the additional tier **45** and the adjacent main tiers **35** and **36** may be somewhat increased; in the aerial under review, this distance equals $0.75\ \lambda_o$.

An example of an aerial with a directional radiation pattern is furnished by an aerial consisting of four tiers **61** through **64** (FIG. **8**) mounted upon a cylindrical support **65** with a diameter $D = 1.17\ \lambda_o$. Each tier **61** through **64** of the given aerial comprises three radiators **66** which, according to the invention, are arranged equidistantly along a portion of the periphery of the cross-section of the support **65**, within a sector of less than 360°, and are energized with currents having different phases. In this embodiment, the sector of the equidistant arrangement of the radiators **66** equals 180°.

The angle of the consecutive offset in azimuth of the radiators **66** from the upper tier **61** to the lower tier **64** is $(\psi/4) = 22.5°$, where ψ is an angle between adjacent radiators, with phases of the energizing current consecutively increasing by 90°.

The power circuit of this aerial, the embodiment thereof and the structure of the radiator are analogous to those of the aerial in FIG. **1**.

Reference numeral **67** in FIG. **8** indicates radio frequency lines of an equal length connecting the radiators **66** of each tier to one point of connection **68** which is connected, by means of radio frequency lines **69** through **72** and via point of connection **73**, to a power source **74**. The lines **69** through **72** differ in their length by $(\lambda_o/4)$, $-(\lambda_o/2)$ and $3/4\ \lambda_o$.

An embodiment of an aerial with a directional radiation pattern and with an additional tier of additional radiators is illustrated in FIG. **9**. The aerial comprises eight main tiers **75** through **82** of radiators **83** and one additional tier **84** of additional radiators **85** mounted upon a current-conducting cylindrical support **86** with a diameter $D = 1.17\ \lambda_o$.

Each main tier **75** through **82** comprises three radiators **83** arranged equidistantly along a portion of the periphery of the cross-section of the support **86**, which is less than 360°, and are energized with currents of different phases. In the present example, this portion of the periphery equals 180°. The angle of the consecutive offset in azimuth of the radiators **83** from the upper tier **75** to the lower tier **82**, $(\psi/4) = 22.5°$, whereas the phases of the current energizing them increase in consecutive order by an angle of 90°. The additional tier **84** comprises sixteen additional radiators **85**. The structure and arrangement of said additional tier **84**, the power circuit of the aerial and its embodiment and the structure of the radiator are analogous to those of the aerial in FIG. **3**. The reference numerals **87** and **88** indicate radio frequency lines of an equal length connecting the radiators **83** and the additional radiators **85**, respectively, to one of points of connection **89** and **90**, respectively, which are coupled, by means of radio frequency lines **91** through **95** and via a point of connection **96**, to a power source **97**. For greater clarity, only one point of connection of four radiators **85** in the additional tier **84** is shown.

An example of an aerial with passive dipoles in each tier for obtaining a non-directional radiation pattern in the horizontal plane is shown in FIG. **10**.

The frequency range of this aerial is 88 to 108 MHz.

The aerial is mounted upon a current-conducting cylindrical support **98** with a diameter $D = 0.14\ \lambda_o$ and comprises eight tiers **99** through **106** of radiators **107** and passive dipoles **108**. In the present example, the radiators **107** are arranged equidistantly along the entire periphery of the cross-section of the support **98**. The power circuit of the aerial under review, the embodiment thereof and the structure of the radiator are analogous to those of the aerial in FIG. **1**. The reference numeral **109** indicates radio frequency lines of an equal length connecting the radiators **107** to one point of connection **110**, which are coupled by means of radio frequency lines **111** through **114** and via a point of connection **115** to a power source **116**.

The angle ψ (FIG. **11**) between the radiators **107** is equal to 180°. In each tier, these radiators are energized with cophasal currents. In addition, each tier of the aerial comprises two (which is the number of radiators) passive dipoles **108** which are arranged in immediate proximity to the radiators **107** (FIG. **10**) and equidistantly along the periphery of the cross-section of the support **98** and which are offset in azimuth relative to the radiators **107** by an angle of 45°. The angle of displacement of the radiators **107** and the passive dipoles **108** following a consecutive turn from tier to tier, $(\psi/4) = 45°$, whereas the phases of the energizing current are changed inconsecutive order by 90°. The angle of displacement of the passive dipoles **108** with respect to the radiators **107** may assume other values, depending upon the ratio D/λ_o and an angle ψ between radiators in a tier.

The radiator **107** (FIG. **11**) is analogous to the radiator **14** (FIG. **2**) and is made as the hollow metal cylinder **23** (FIG. **11**) with the lid **24**, fastened to the support **98** by means of the metal flange **25** and the insulator **26**. The passive dipole **108** in the present example is made as a hollow metal cylinder **117** with a length of close to $\lambda_o/4$ covered at its outer face end by a lid **118**. Said cylinder **117** is electrically connected to the support **98**. Used instead of the above-listed passive dipole may be other assymmetrical radiators electrically connected to the support.

Examples of embodiments of an aerial with a non-directional radiation pattern in the horizontal plane, with passive dipoles in the main tiers and an additional tier of additional radiators; of an aerial with a directional radiation pattern in the horizontal plane with passive dipoles in the main tiers and an additional tier of additional radiators are not given, since it is easy, with the aid of those contained in the present disclosure, to build such aerials, in accordance with the invention.

In discussing the operating principle of the proposed aerial illustrated in FIGS. **1** and **3**, we shall only consider radiation patterns of one tier.

If the angle ψ between adjacent radiators **14, 44** of the main tier **2, 28** is selected to be less than an angle $\beta = [(\alpha\lambda_o/D) \cdot 5.73]°$ the radiation pattern of one tier $F_1(\phi)$ in the horizontal plane (FIG. **12**) is described, with a high degree of accuracy, by the function

$$F_1(\phi) = \cos[(2\pi/\psi)\phi],$$

where ϕ is the varying angle in the azimuthal plane.

As the adjacent tier **3, 29** is offset in azimuth by an angle $\psi/4$ and its current phase is displaced by an angle of 90°, the radiation pattern of this tier is described as follows:

$F_2(\phi) = J\cos[(2\pi/\psi)(\phi + \psi/4)] - = J \cdot \sin[(2\pi/\psi)\phi]$.

The resultant radiation pattern of both tiers is as follows. $F(\phi) = F_1(\phi) + F_2(\phi) = e^{-j\frac{2\pi}{\psi}\varphi}$, which correpond to a circular radiation pattern.

Suppose we divide the entire aerial (FIG. **1**) into pairs of adjacent tiers; we shall note, then, that their fields add together and that the radiation pattern of the entire aerial is also circular.

The radiation pattern (FIG. **13**) of the aerial of FIG. **1** in the mid-band frequency is uniform within ±1.5 dB. In the frequency range corresponding to TV Band **11** (±0.15 λ_o) the radiation pattern is uniform within ±1.8 dB.

The production of a non-directional radiation pattern by the additional tier **45** (FIGS. **3** and **5**) may be explained in a similar way. Its additional radiators **46** are energized with a phase of 0° and 180° and form radiation patterns which are described as follows:

$F_1(\phi) = \cdot\cos[(2\pi/\psi)\cdot\phi]$

The radiation pattern of the radiators **46** that are energized with a phase of 90° and 270° is displaced in space by an angle $(\psi/4) = 22.5°$. Taking into account the fact that the phase of the fields radiated by adjacent additional radiators **46** is shifted through 90°, the overall radiation pattern of the additional tier **45** also turns out to be non-directional.

In order to fill the zeros in the radiation pattern in the vertical plane, the additional tier **45** of the aerial under review is additionally displaced in phase by 30°. A similar effect may be obtained by respectively shifting the additional radiators **46** of the additional tier **45** through an appropriate angle in azimuth relative to the remaining radiators.

The aerial has additional provisions for compensating the radiation characteristic in the vertical plane. It is seen from FIGS. **3** and **5** that the extreme main tiers **28** and **43** in which the radiators **44** are energized with a phase of 0° are located farther from the additional tier **45** than the main tiers **29** and **42** whose radiators **44** are energized with phases of 270° and 90°.

This may somewhat raise the non-uniformity of the radiation pattern in the horizontal plane, which is prevented by additionally shifting the radiators **44** of the main tiers **28, 35, 36** and **43** by an angle $\Delta = 4°$. The direction of the additional shift of the radiators **44** of the above-listed main tiers are shown in FIG. **5**. The experimental radiation pattern of the aerial shown in FIG. **3** in the midband frequency (FIG. **14**) is uniform within ±1.3 dB. In the frequency range of TV Band III (±0.14 λ_o), the radiation pattern is uniform within ±1.8 dB.

The directional radiation pattern shown in FIGS. **8** and **9** is marked by the fact that the portion of the periphery of the cross-section of the supports **65** and **86**, respectively, placed equidistantly within which in the main tiers **61** through **64** and **75** through **82** are the radiators **66** and **83**, is less than 360°.

The radiation pattern of the aerial shown in FIG. **8** in the mid-band frequency range (FIG. **15**) is uniform in the serviceable sector, which is close to 180°, within ±1.5 dB, and within ±2.2 dB in the frequency range of ±0.15.

The principle of forming the radiation pattern of the aerial in FIG. **10** with the radiators **107** and the passive dipoles **108** is analogous to that of FIGS. **1** and **3**.

The radiation pattern of the aerial in the mid-band frequency (FIG. **16**) is uniform within ±0.8 dB. At the extreme frequencies of the range of ±0.1 λ_o, the radiation pattern is uniform within ±1.1 dB.

In contrast to the currently employed transmitting stacked aerials, in the proposed aerial (owing to the fact that its tiers are turned in consecutive order by an angle $\psi/4$ and that radiators of each next tier are fed with currents displaced in phase by 90°) it is possible to substantially reduce the intercoupling between the tiers of the radiators. As a result, the radiation pattern obtained is close to the required one. Experimental data obtained with the use of the proposed aerial with different ratios (D/λ_o in the operating frequency range corroborate the assertion that the given aerial is capable of producing radiation patterns which are less non-uniform than those of the existing aerials.

Equidistant distribution of radiators in the tiers with an angle between adjacent radiators determined by the ratio D/λ_o enables the proposed aerial to operate on supports of any diameter, with an optimum number of radiators in the tiers.

Energizing radiators in the tiers with cophasal currents makes the radiation pattern practically independent of the geometry of the radiators, which substantially facilitates the adjustment of the aerial.

The use of radially oriented radiators reduces wind loads and accounts for the simplicity of design; this makes for a simple and effective protection of their input from the atmospheric effects, improves conditions for operation, servicing and repair and considerably raises the reliability of the aerial.

What is claimed is:

1. A transmitting stacked aerial comprising:
a current-conducting cylindrical support;
several tiers of radiators mounted on said support and radially oriented with respect to the surface thereof;
each said tier comprising a preset number of said radiators arranged equidistantly within at least some portion of the periphery of the cross-section of said support;
said radiators of each said tier offset in azimuth relative to the respective radiators of the adjacent tier by a preset angle;
said angle of turn of the adjacent tiers being equal to $\psi/4$, where ψ is an angle between adjacent radiators in the same tier, the turn being effected from tier to tier inone direction;
said angle ψ between adjacent radiators in the same tier being less than an angle $\beta = [(2\lambda_o/D) \cdot 57.3]°$, where D is the diameter of said support, and λ_o is the mid-band wavelength:
radio frequency lines of an equal length electrically interconnecting said radiators of each tier to one point of connection, which provides for energizing the radiators in each tier with cophasal currents; 9
a power source of said radiators electrically connected to said points of connection so that the currents energizing the radiators of adjacent tiers are displaced in phase by 90°, said displacement in phase being effected from tier to tier in one direction.

2. A transmitting stacked aerial comprising:
a current-conducting cylindrical support;
an even number of main tiers of radiators mounted upon said support and radially oriented with respect to the surface thereof;
each said tier comprising a preset number of said radiators arranged equidistantly within at least some portion of the periphery of the cross-section of said support;
said radiators of each said tier being offset in azimuth relative to the respective radiators of the adjacent tier by a preset angle;
said angle of turn between adjacent tiers equal to $\psi/4$, where ψ is an angle between adjacent radiators in the same tier, the turn from tier to tier being effected in one direction;
said angle ψ between adjacent radiators in the same tier being less than an angle $\beta = [(2\lambda_o/D) \cdot 57.3]°$, where D is the diameter of said support, and λ_o is the mid-band wavelength;
one additional tier of additional radiators designed to eliminate troughs in the radiation pattern in the vertical plane, arranged in the middle of the radiating portion of the aerial symmetrically with regard to the first and last main tiers;
additional radiators arranged equidistantly along the periphery of the cross-section of said support and radially oriented relative to its surface, an angle Σ between adjacent additional radiators being less than an angle

$$\gamma = [(\lambda_o/2D) \cdot 57.3]°$$

first radio frequency lines of an equal length electrically interconnecting said radiators of each main tier to one point of connection, which makes for energizing the radiators in each main tier with cophasal currents;
second radio frequency lines of an equal length electrically interconnecting the additional radiators, which are offset in azimuth relative to one another by an angle of 4 Σ, to one point of connection, which ensures energizing these radiators with cophasal currents;
a power source of said main radiators and additional radiators electrically connected with said points of connection of the main tiers so that the currents energizing the main radiators in adjacent tiers are displaced in phase by 90°, said phase displacement being effected in consecutive order from tier to tier in one direction;
said power source electrically connected to said points of connection of the additional tier so that the currents energizing adjacent additional radiators are displaced in phase by 90°, said phase displacement being effected in consecutive order from radiator to radiator so that the direction of that phase displacement from radiator to radiator of the additional tier in the direction of the selected turn of adjacent main tiers coincides with that of the phase displacement of the main radiators of the main tiers from tier to tier following the turn thereof.

3. A transmitting stacked aerial, as claimed in claim 1, wherein a preset portion of the periphery of the cross-section of the support is determined by the entire perimeter of that cross-section of the support and is equal to 360°.

4. A transmitting stacked aerial, as claimed in claim 2, wherein a preset portion of the periphery of the cross-section of the support is determined by the entire perimeter of that cross-section of the support and is equal to 360°, said angle Σ between adjacent additional radiators being four times less than said angle ψ.

5. A transmitting stacked aerial, as claimed in claim 1, wherein arranged in immediate proximity to said radiators in each said tier are passive dipoles whose number is equal to that of the radiators and which are mounted upon said support and are radially oriented with regard to the surface thereof.

6. A transmitting stacked aerial, as claimed in claim 2, wherein arranged in immediate proximity to the main radiators in each main tier are passive dipoles whose number is equal to that of the radiators and which are mounted upon said support and are radially oriented with regard to the surface thereof.

7. A transmitting stacked aerial, as claimed in claim 3, wherein arranged in immediate proximity to said radiators in each said tier are passive dipoles whose number is equal to that of the radiators and which are mounted upon said support and are radially oriented with regard to the surface thereof.

8. A transmitting stacked aerial, as claimed in claim 4, wherein arranged in immediate proximity to the main radiators in each train tier are passive dipoles whose number is equal to that of the radiators and which are mounted upon said support and are radially oriented with regard to the surface thereof.

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