

July 4, 1967

H. LAUB ETAL

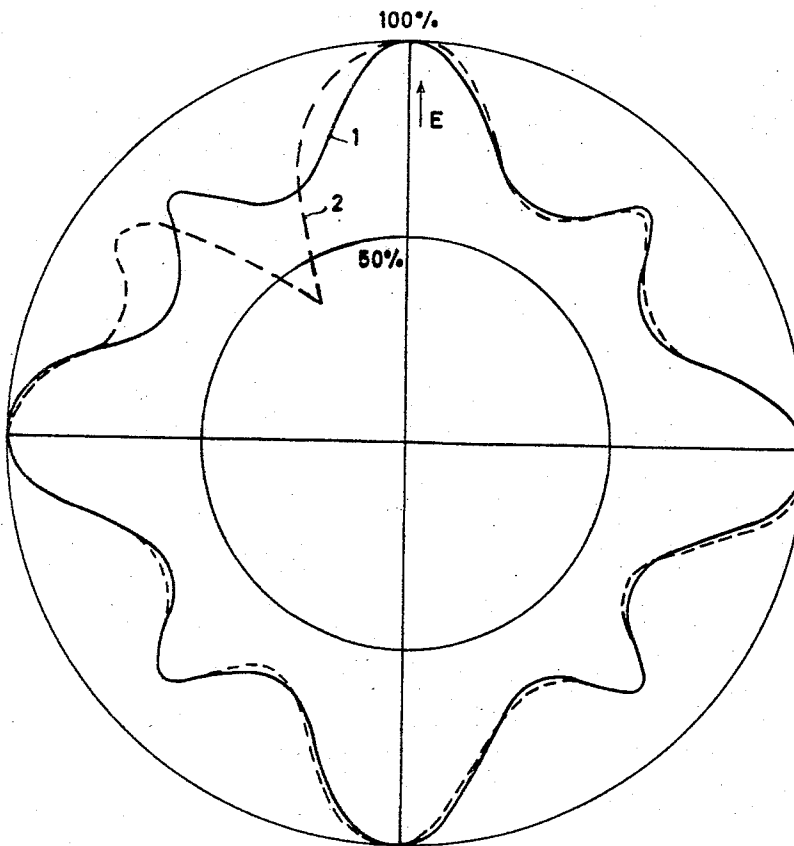
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ANTENNA COMPRISING GROUPS OF RADIATORS DISPOSED IN
DIFFERENT PLANES

Filed July 30, 1963

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Fig. 1



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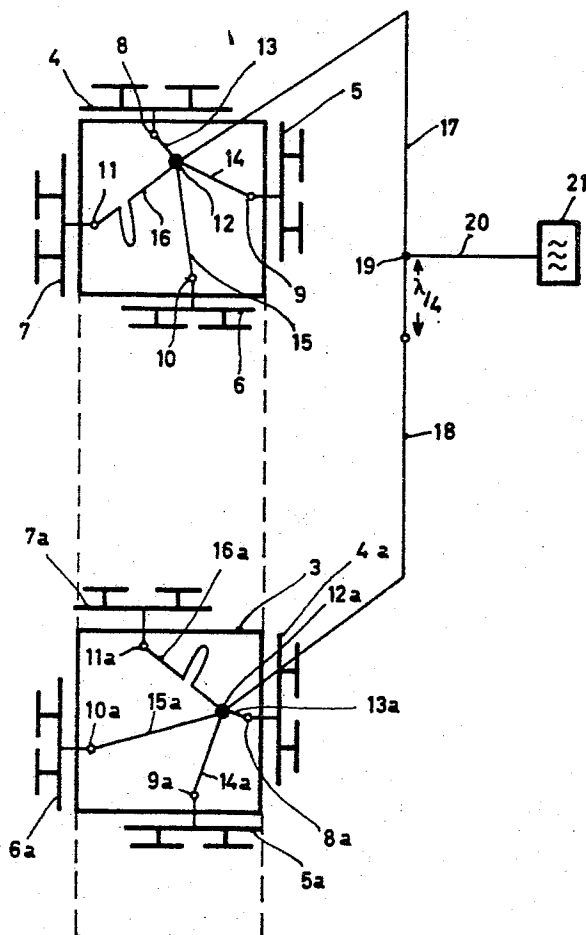
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Fig. 2



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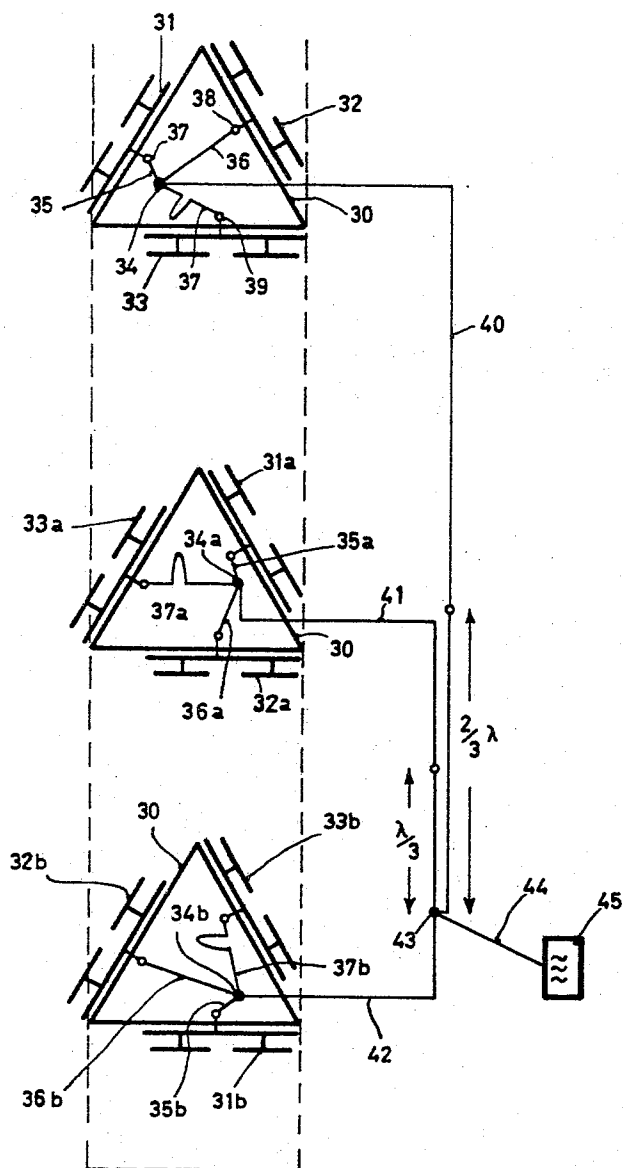
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Fig. 3



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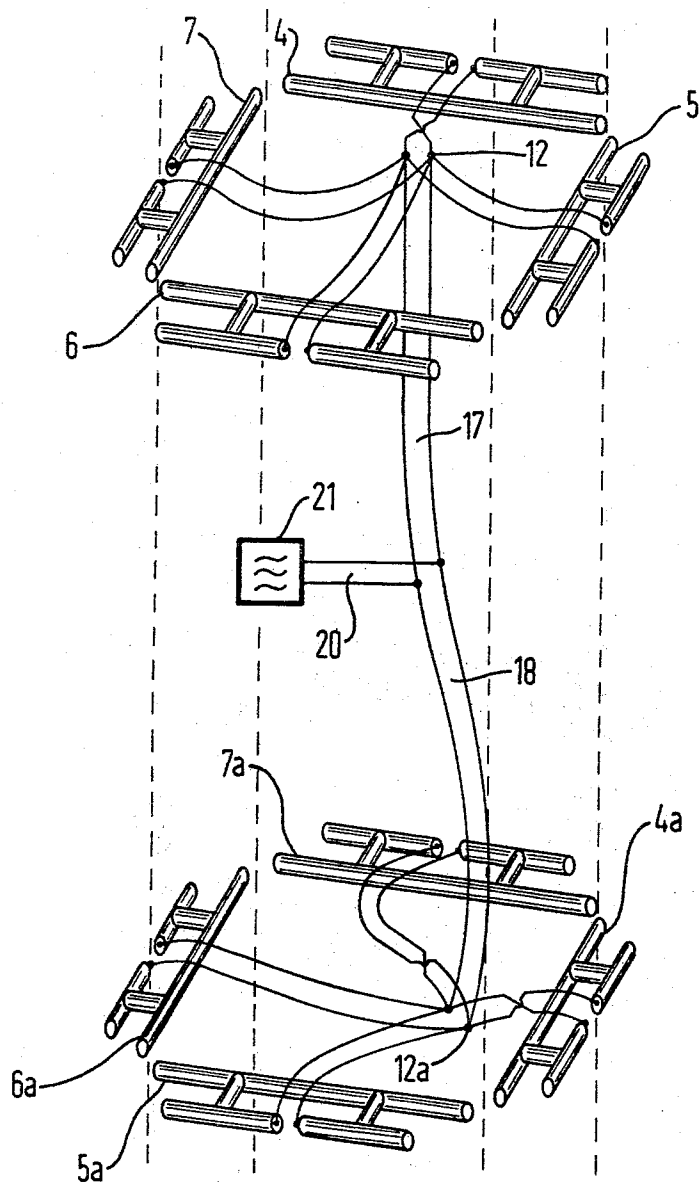
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Fig. 4



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ANTENNA COMPRISING GROUPS OF RADIATORS DISPOSED IN DIFFERENT PLANES

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6 Claims. (Cl. 343-796)

The invention disclosed herein is concerned with an antenna arrangement or array comprising groups of radiator elements disposed on a mast one above the other in different planes, the radiator elements of each group being fed in rotary field, and utilizing phase compensation for connecting together radiator groups of different planes.

It is known to feed antennas mutually with different phase so as to obtain improved matching. The radiators are in these known arrangements mutually staggered so that a radiator which is fed with lagging phase is in radiation direction preferred. This is done in order to compensate for the different phase-dependent changes in the radiation diagram.

An arrangement has become known for producing omnidirectional radiation diagram, wherein respective groups of radiators are disposed in a polygonal arrangement, for example, about a mast, and fed in rotary field. There is in such arrangement a phase difference of $360/n$ degrees between the individual radiator elements of a radiator group, wherein n indicates the number of radiator elements forming the group. These phase differences which are required for the rotary field feed, are as a rule produced by cable lines which extend from a common distribution point to the radiator elements and which are accordingly of different length.

It is in connection with antennas comprising, for sharp vertical focusing, radiator groups which are arranged one above the other and respectively fed in rotary field, known to use the phase feed serving for the improvement of matching, also for the radiator groups disposed in different levels or planes. The distribution points associated with radiator groups of different planes are, in a known arrangement of this kind, fed with 90° phase shift, which makes it possible to obtain an improvement in the matching at the point at which the feed lines are connected together. Since the radiation diagram is thereby affected, owing to the different phase conditions at the distribution points of different planes, additional cable lines are in the known antenna arrangement disposed between the distribution point and the individual radiator elements, so as to compensate the advancing feed phase appearing at one of the distribution points.

In antenna arrangements comprising radiator groups the radiation elements of which are fed in rotary field, there will result, upon deviation from the median frequency, a growing departure from the circularity of the radiation diagram, the greatest breaks or dents appearing thereby between those of the radiators which have the maximum phase step. At the median frequency for which the antenna arrangement is designed, the phase steps from one to the other radiator element of the radiator groups are equally great and there will therefore result a repetitious course of the radiation distribution for each quadrant of the horizontal diagram. Upon effecting now, for example, in the case of four radiator elements of a group, fed in rotary field with a phase step always of 90° , the required phase shifts with the aid of cable lines which are from one to the other radiator element always longer by $\lambda/4$, there will result, upon deviation from the median frequency, for which the cable

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lengths are designed, a deeper break or dent between the radiator elements with the phase 270° and the phase 0° , because the phase step is here due to the deviation of the operating frequency from the median frequency, respectively greatest or smallest. In the known antenna arrays which provide for improved matching a phase feed for radiator groups disposed one above the other, these dents or breaks of the radiation diagram will likewise occur one above the other, and the resultant radiation diagram will accordingly become strongly unsymmetrical.

The main object of the invention is to obtain, upon using in connection with radiator groups, the phase feed and the improved matching connected therewith, a more uniform wide band radiation diagram and to simplify at the same time the construction of the antennas.

According to the invention, this object is achieved by the provision of an antenna structure of the initially indicated kind, wherein phase differences obtain between the distribution points of neighboring radiator groups which lie in different planes, the magnitude of such phase differences corresponding to the phase step from one to the other radiator element of the radiator group, and wherein the distribution lines for the radiator groups of individual planes, which lie between the distribution points and the radiator elements and serve for the production of the phase steps, are mutually identical, and wherein the radiator groups of the individual planes are respectively mutually rotated or staggered by a value corresponding to the phase step between the radiator elements, so that the radiator elements lying one above the other have the same phase.

The application of these measures does not adversely affect the matching of the feed line to the individual radiator groups, which remains good and unaltered, while the rotation or staggering of the radiator groups by a value corresponding to the difference of the feed phases and at the same time to the phase step, results in a rotation of the radiation diagram such, that the breaks or dents caused by the frequency course, are mutually displaced. Since the difference of the feed phases corresponds at the same time mutually to the phase step of the radiator elements of the radiator groups, such rotation or staggering will have the effect of rectifying the phase relation between radiator elements of different groups, lying one above the other, so that they are operated in the same phase. This makes it possible to provide for the radiator elements lying in different planes, identical disposition, proceeding from the distribution point, of the cable lines which effect the phase steps, such lines extending to the radiator elements of the respective groups. Accordingly, identically equipped components of prefabricated antenna arrays can be placed one above the other and can be spatially angularly staggered or displaced in simple manner incident to the assembly thereof. Moreover, cable lines which are otherwise required for the compensation of phase relations and the attenuation caused thereby, are eliminated.

The rotation or staggering of the radiator groups of different planes is advantageously effected so that they are mutually in alignment as seen from the ends thereof. The exterior of the antenna array along the mast is in this manner always uniformly constructed. In an antenna array according to the invention, the radiators or radiator groups are in known manner advantageously shifted along the sides of the mast, thereby improving the radiation diagram appearing for the median frequency as to the uniformity thereof.

There are in addition to this known shifting of the radiator elements along the sides of the mast, other measures of advantage which result as such in a more

wide band radiation characteristic. This includes measures already proposed elsewhere, in connection with radiators which are fed with different phase, for example, in rotary field, according to which the principal radiation directions of those of the radiators at which the phase step between the radiator elements grows with increasing frequency, embrace mutually a greater angle than is embraced by the principal radiation directions of radiators at which the phase step decreases with increasing frequency.

Another advantageous possibility for obtaining more uniform wide band radiation diagrams resides in that the angular rotation or staggering of the radiator elements of a plane, serving for the compensation of disturbances of the radiation diagram, which are caused by the differing phase, is effected so that the spacing between the radiation centers of gravity of those of the radiation elements at which the phase step grows with increasing frequency, is made greater than that for radiators at which an increasing frequency signifies a decrease of the phase step.

The uniformity of the radiation diagram can also be advantageously improved, upon transmitting greater frequency ranges, by relating the angular staggering of the radiation elements of radiator groups, serving for the compensation of the phase relations, to a wave length which corresponds to a frequency lying above the median frequency of the frequency band which is to be transmitted.

Further details and features will appear from the appended claims and from the description of the invention which is rendered below with reference to the accompanying drawings.

FIG. 1 represents the radiation diagram of a radiation group comprising four radiator elements;

FIG. 2 shows the feed of two radiator groups disposed one above the other on a four-sided mast;

FIG. 3 indicates the feed of radiator groups each comprising three radiator elements, arranged on a three-sided mast; and

FIG. 4 is a perspective view of two radiator groups disposed one above the other, schematically illustrating the feed lines and their connections.

In FIG. 1 is represented the radiation diagram of a radiator group comprising four radiator elements (full wave dipoles). The full line 1 shows the field strength distribution at identical phase feed of the four radiator elements forming a group, while the dash line 2 shows the radiation distribution in the case of radiators fed in rotary field and shifted along the sides of the mast. This antenna corresponds to the arrangement shown at the top in FIG. 2, the direction of the arrow E corresponding to the principal radiation direction of the field 4. It is thereby assumed that the operating frequency of the radiators lies in both cases approximately at $1.18f_m$, wherein f_m indicates the median operating frequency for which the radiators and the feed lines are designed. In the case of the radiator groups fed in rotary field, there appears a deep break or dent between the radiator fed with 270° phase shift and the radiator fed with 0° phase shift. It is assumed here that the lengths of the feed lines of individual radiators, proceeding from the distribution point, are respectively greater by $\lambda/4$. This results in the appearance, between the radiator operated with 0° and the one operated with 270° (referred to the median frequency) at higher frequencies, in a particularly small and at the lower frequencies in a particularly great phase step, which produces a great unsymmetry of the radiation diagram. It is possible to hold the break in the radiation diagram of the radiator group, fed with shifted phase, smaller, by obtaining the phase shifting of 180° (trailing or lagging) not by line lengths, but by changed polarization of feed lines and in case of 270° (trailing or lagging), by change of polarization of the feed line in addition to a cable line of a length of $\lambda/4$. However, the radiation diagram will then have two mutually oppositely directed breaks which are, however, somewhat

smaller than the break shown in connection with the radiation distribution in FIG. 1. One of the breaks will lie at the same point as in FIG. 1 and the second at a point displaced by 180° , that is, between the radiators operated with 90° and 180° phase shift.

FIGS. 2 and 4 illustrate an antenna system comprising two radiator groups disposed in different planes or levels of the array. For simplification of representation, the radiator planes or levels are shown displaced by 90° with reference to the mast edge indicated by dash lines.

The radiator elements of the groups, respectively indicated at 4 to 7 and 4a to 7a, include full wave dipoles which are arranged in front of a reflector wall, and which may also be constructed as dipole lines, disposed one above the other, in the form of antenna fields. The connecting points of the radiator elements or antenna fields are indicated at 8 to 11 and 8a to 11a, respectively. The radiator elements 4 to 7 and 4a to 7a, respectively, are fed by way of cable lines 13 to 16 and 13a to 16a extending to the individual radiator elements from the distribution points 12 and 12a, respectively. There is between the feed lines, proceeding from the line 13 and 13a, respectively, always a difference in length amounting to $\lambda/4$. Upon allocating to the point 8 (radiator 4) the phase 0° , the point 9 (radiator 5) will have a phase lag of 90° , the point 10 (radiator 6) a lag of 180° and the point 11 (radiator 7) a lag of 270° . Accordingly, the arrangement represents a radiator group fed in rotary field, wherein the phase differences are produced by cable lines which extend with increasing length from the distribution point 12. The radiator group shown at the bottom of FIG. 2 is with respect to the length of the feed lines 13a to 16a constructed just like the one shown at the top of the figure and is, moreover, angularly rotated by 90° from the position of the latter.

The feed of the distribution points 12 and 12a is effected by way of lines 17 and 18 which are at the branching point 19 disposed in parallel and connected by way of line 20 with a high frequency voltage source 21. There is a difference in length between the feed lines 17 and 18, amounting to $\lambda/4$, so that the distribution point 12a is provided with a phase lagging by 90° with respect to that of the phase supplied to the distribution point 12. The difference in length, of the feed lines 17 and 18 effects opposed phase transformation of similar mismatching at the distribution points 12 and 12a, thereby improving the matching of the feed line 20.

Since the phase step between the radiator elements of the radiator group amounts to 90° , and since there is between the distribution points 12 and 12a of the neighboring radiation group a phase difference, produced by the feed lines 17 and 18, which likewise amounts to 90° , there can be produced, by angular rotation or staggering of the radiator elements, an antenna arrangement wherein successively disposed radiator elements have the same phase. The radiation diagram of such an antenna will therefore correspond to an arrangement wherein the distribution points are supplied with mutually similarly phased alternating voltages by way of feed lines of identical length.

While FIG. 4, for simplification, illustrates the feed lines in the form of symmetrical lines, usually coaxial lines will be utilized in conjunction with a symmetrizing device for each cooperable pair of radiator elements.

The advantage with respect to wide band characteristic of the radiation diagram will be appreciated upon considering the allocation of the radiation diagram to the radiator groups. The break or dent in the radiation distribution according to FIG. 1 lies in the case of the upper radiator group between the radiator elements 4 and 7, while appearing in the case of the lower radiator group between the radiator elements 4a and 7a, and therefore rotated by 90° . The cooperation of the two radiator groups accordingly results in a considerably more uniform radiation diagram than would be obtained in arrangements in which breaks or dents, occurring upon

deviation from the median frequency, come to lie one above the other. Upon using four radiator groups lying one above the other, each having four radiator elements, the feed may be effected so that the respective break or dent in the radiation diagram always lies in another quadrant.

FIG. 3 shows three radiator groups 31, 32, 33; 31a, 32a, 33a; 31b, 32b, 33b, which are disposed one above the other and mounted on a mast. The respective radiator elements are fed by way of lines 35, 36, 37; 35a, 36a, 37a; 35b, 36b, 37b, extending from respectively common distribution points 34, 34a, 34b, resulting in phase steps between the individual radiators, amounting always to 120°. Upon allocating or assigning the phase 0° to the connecting or distribution point 37, there will be obtained a lagging phase of 120° for the point 38 (radiator 32), and for the point 39 (radiator 33), a lagging phase of 240°. Between the radiator elements 31 and 32, there will be obtained, responsive to deviation from the median frequency, a dent in the radiation diagram in a manner analogous to that explained in connection with FIGS. 1 and 2.

The distribution points 34, 34a and 34b are respectively supplied by way of lines 40, 41, 42, the length of such lines increasing from one to the other radiator group always by $\frac{2}{3}\lambda$. This manner of feeding, serving for improving the matching at the interconnecting point 43 and therewith of the feed line 44 of the transmitter 45 is, with respect to the phase position of the radiation diagrams compensated respectively by angular rotation or staggering of the radiator elements of the radiator groups, with respect to the common distribution points 34, 34a and 34b, so that radiators with similar phase come to lie one above the other.

The greatest break or dent occurring in the radiation diagram responsive to frequency deviation will accordingly always lie between the radiators 31 and 32; 31a and 32a as well as 31b and 32b, thus moving about the mast. The radiation diagrams of the individual radiator groups will therefore result, upon superposition thereof, in a wide band strongly circular radiation diagram.

The invention is not inherently limited to the use of the described and illustrated radiator groups having respectively three or four radiator elements, but may be advantageously applied, with appropriate allocation between the phase steps and the radiator elements as well as the differences of the feed phases of the distribution points, irrespective of the number of radiator elements. The considerations explained in connection with the embodiments for individual radiators, apply analogously in the case of antennas which operate, instead of with individual radiators, with line-like arranged antenna fields which are supplied by way of a common feed point and fed in phase.

Changes may be made within the scope and spirit of the appended claims which define what is believed to be new and desired to have protected by Letters Patent.

We claim:

1. An apparatus arrangement including a plurality of groups of radiator elements disposed on a mast one above the other in different planes, each group having a plurality

of radiator elements positioned about a common feed distribution point for radiation in different directions in angular phase steps, lines of different length extending from the common feed distribution point of each group to the respective radiator elements thereof, the respective lines of corresponding phase steps in the respective groups of radiator elements being of identical length, means for feeding the radiator elements in each group in rotary field by way of said lines which produce said phase steps, feed means producing phase compensation for connecting the field distribution points of the respective groups of radiator elements disposed in different planes, there being phase differences between the feed distribution points of neighboring radiator element groups disposed in different planes, the magnitude of said phase differences corresponding to the phase step from one to the other radiator element of the respective group, the groups of radiator elements being rotated in their respective planes by an angular amount corresponding to the amount of the phase step obtaining between the radiator elements so that radiator elements of a group of the respective groups disposed one above the other for radiation in the same direction operate with the same phase.

2. An antenna arrangement according to claim 1, wherein groups of radiator elements in the various planes are angularly rotated so that the radiator elements thereof are along the mast in mutual alignment.

3. An antenna arrangement according to claim 1, wherein each group of radiator elements comprises four radiator elements, means for connecting radiator groups disposed in different planes pair-wise in parallel, and means for feeding said parallel connected radiator groups with a 90° phase difference.

4. An antenna according to claim 1, wherein the principal radiation directions of those of the radiator elements of a group, in which the phase step increases with increasing frequency, embrace mutually an angle which is greater than the angle embraced by the principal radiation directions of radiator elements in which the phase step decreases with increasing frequency.

5. An antenna according to claim 1, wherein the angular rotation of the radiator elements of a group of radiator elements, serving for the compensation of disturbances of the radiation diagram caused by different phase, is so effected that the spacing between those of the radiation center points at which the phase step increases with increasing frequency, is greater than for those of the radiator elements at which an increase of frequency signifies a decrease of the phase step.

6. An antenna arrangement according to claim 1, wherein the angular rotation of the radiator elements of a group of radiator elements along the sides of the mast, is referred to a wave length which corresponds to a frequency lying above the median frequency of the frequency band to be transmitted.

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