

Nov. 26, 1968

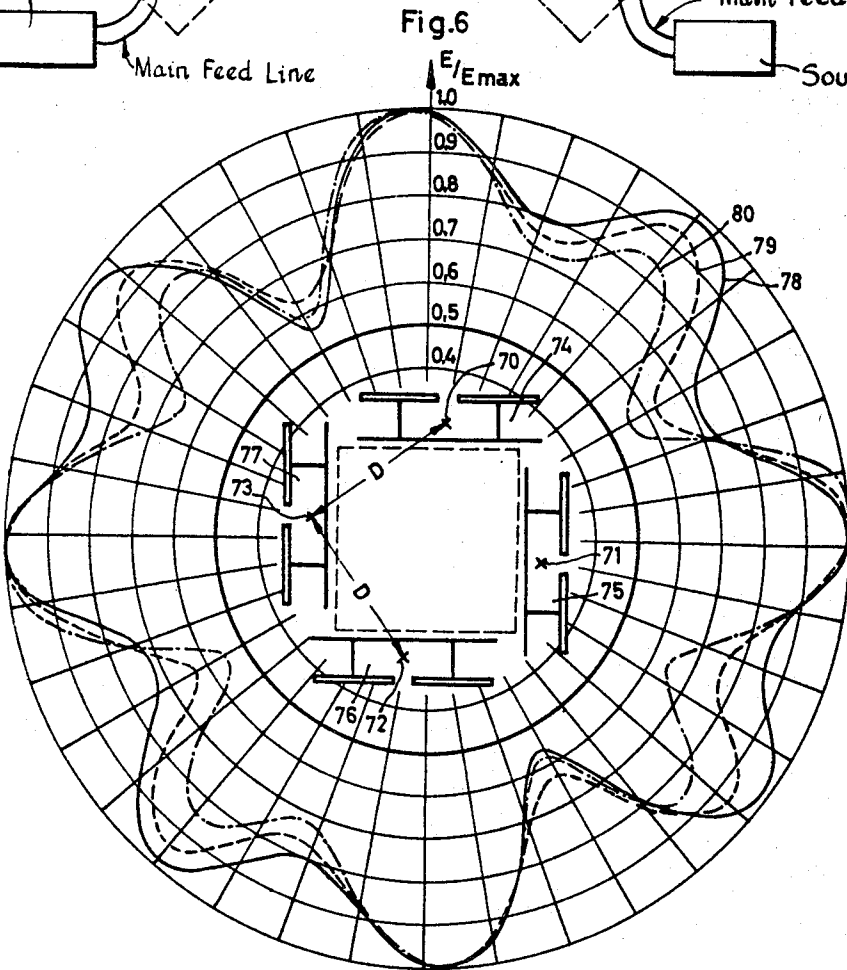
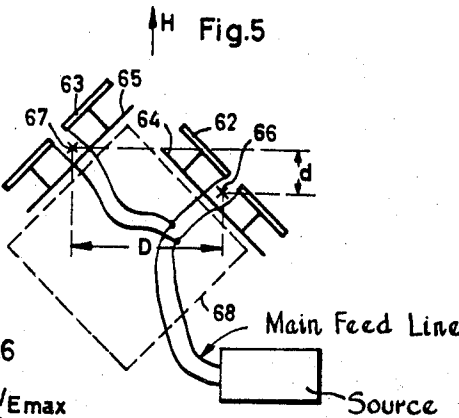
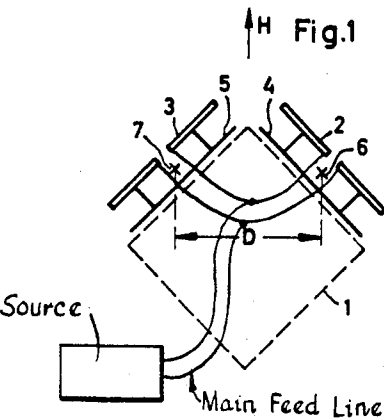
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ANTENNA HAVING AT LEAST TWO RADIATORS FED WITH DIFFERENT PHASE

Original Filed Nov. 21, 1962

3 Sheets-Sheet 1



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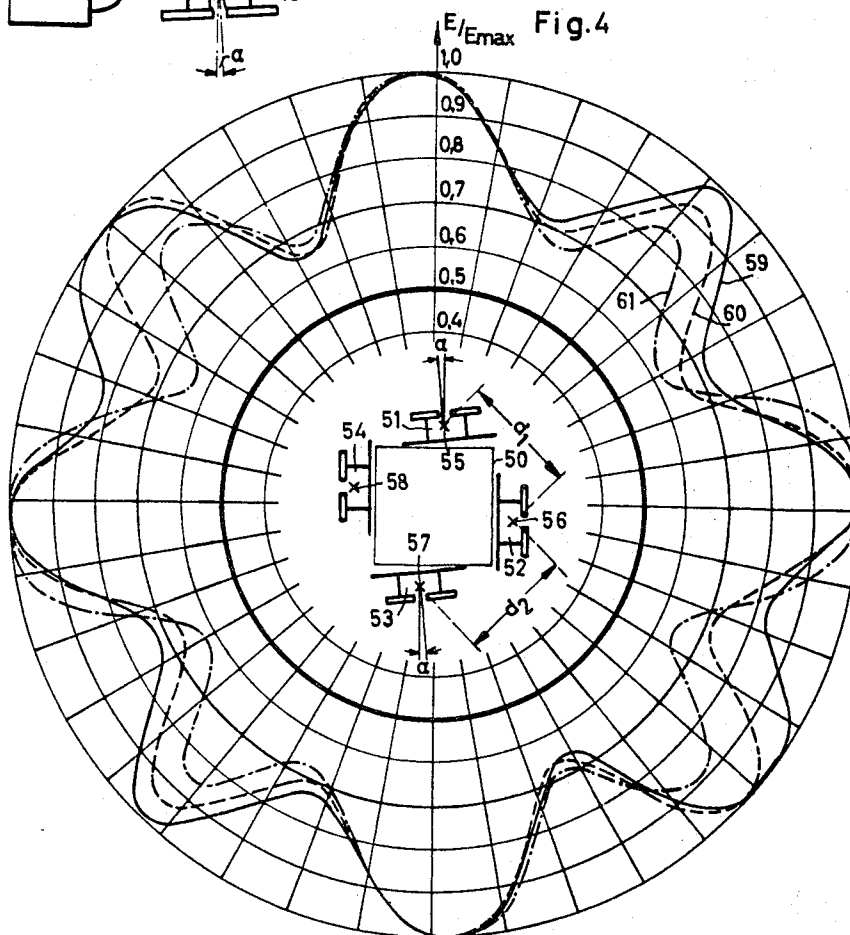
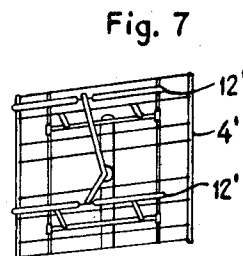
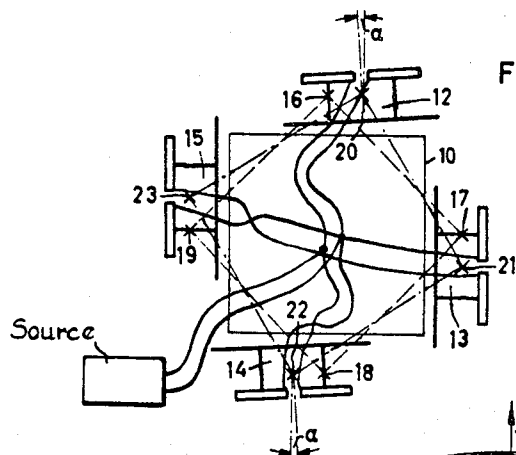
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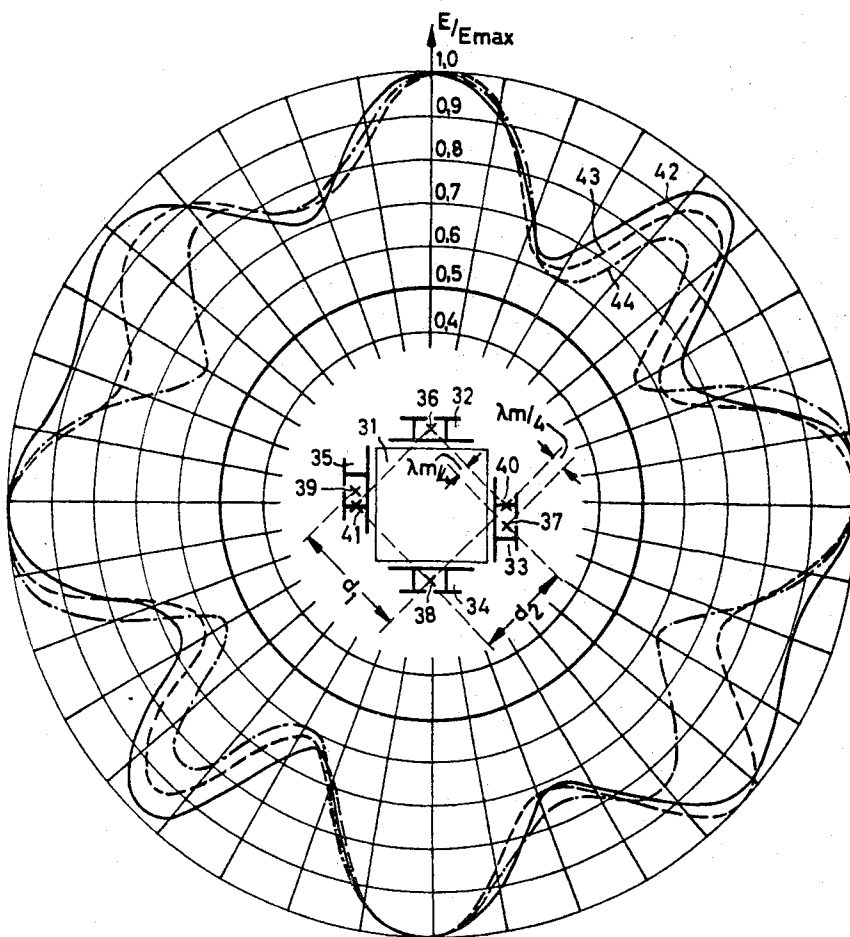
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ANTENNA HAVING AT LEAST TWO RADIATORS FED WITH DIFFERENT PHASE

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Fig.3



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ANTENNA HAVING AT LEAST TWO RADIATORS FED WITH DIFFERENT PHASE

Helmut Laub and Claus Hoyer, Munich, Germany, assignors to Siemens Aktiengesellschaft, Munich, Germany, a corporation of Germany

Continuation of application Ser. No. 240,200, Nov. 21, 1962. This application Sept. 7, 1967, Ser. No. 666,216

Claims priority, application Germany, Nov. 23, 1961,

S 76,808, S 76,809, S 76,810

12 Claims. (Cl. 343—800)

ABSTRACT OF THE DISCLOSURE

An antenna arrangement having a relatively circular radiation pattern in the transmission range, employing at least three radiators which are fed with different phasing and enclose, in the base arrangement, respective angles between their main radiation directions, in which between one radiator pair, on a change in the frequency, there occurs an increase, and between another radiator pair a decrease in the difference in the feed phases, the angles between the main radiation directions of adjacent radiators being such that radiators, between which the difference in the feed phases becomes greater with increasing frequency, enclose a greater angle between their main radiation directions than those radiators between which the difference in the feed phases becomes less with increasing frequency.

This is a continuation of application Ser. No. 240,200, filed Nov. 21, 1962, now abandoned.

The invention disclosed herein is concerned with an antenna arrangement comprising at least two radiators or radiator groups which are respectively fed with different phase signals.

It is known to feed different loads or antenna radiators with different phase signals, such that the respective reflective energy components on the lines are cancelled in the direction of the energy source. Such an arrangement results, with appropriate dimensioning of the feed lines extending to the individual loads, in an improved matching with respect to the common feed line.

The feed of the radiators in the above described manner results in a disadvantage in the case of antenna arrangements, namely, that there is a distortion of the radiation pattern due to the components of the energy which are radiated with different phases. Such distortion may be compensated in a known manner by spatially displacing the antenna radiator elements in accordance with the different feed phase. In the case of a directional antenna which comprise two radiators arranged on a straight line, and which radiators are fed with signals having a phase difference of 90° and wherein the principal radiation directions of which are the same, the radiator fed with lagging phase is accordingly displaced in the radiation direction by $\lambda/4$, whereby the distortion of the radiation diagram which is caused by the phase shift, is practically cancelled. The spatial displacement of the radiation center points, referred to the principal radiation direction, is likewise $\lambda/4$. The radiation diagrams of such spatially displaced radiator arrangements correspond substantially to those obtained with radiators which are fed with the same phase.

It is known to use a plurality of individual antennae in appropriate grouping, for example, in the form of dipole fields, so as to obtain a sector-like or circular radiation diagram. The simplest examples of antennae of this kind are represented by dipole fields arranged on the sides of a mast, such fields being in the case of an omnidirectional radiation diagram uniformly distributed about the

mast; in the case of a sector-like radiation diagram, all sides of the mast are not provided with dipole fields. If it is desired, in connection with such antenna arrangements, desired to make use of the phase shifted feed of the radiators, there must be effected, in the radiating plane of the system, a displacement of the radiation center points so as to obtain a compensation of the distortion caused by the phase shifted feed. Accordingly, in the case of four dipole fields arranged respectively with 90° phase difference on the sides of a square mast, the total displacement of the radiation center points of two respective dipole fields, referred to the half angle line of the principal radiation directions, amounts to $\lambda/4$. Therefore, the radiation center points must be displaced by $\lambda/4\sqrt{2}$ along the respective side of the mast. The displacement of the radiation center points refers to the half angle line between the principal radiation directions because, with identical phase feed of the two radiators, the radiation components will likewise superpose in identical phase in the corresponding direction. The wave length to which this displacement is related corresponds to the frequency which is to be radiated. However, upon transmitting a greater frequency band, there will again appear greater breaks in the radiation diagram, resulting from the fact that the means serving for the production of different feed phases, for example, cables of given length, do not produce at the input of the radiators the desired phases for other frequencies. Moreover, the spatial displacement, and therewith the compensation of the distortions of the radiation diagram caused by the phase shift, does not apply at other frequencies. The spatial displacement and the antenna arrangements thereby obtained are accordingly of narrow band character insofar as the uniformity of the radiation diagram is concerned.

The principal object of the invention is to avoid these drawbacks of the known arrangements and to render the radiation diagrams more uniform over a broad band, even in connection with antenna arrangements having radiators fed with different phase.

According to the invention, this object is achieved in connection with an antenna arrangement having at least two radiators fed with different phase, by so disposing the radiators that the main radiation directions of the radiators in which the phase difference between the feed phases becomes greater with increasing frequency, embrace with each other an angle which is greater than the angle embraced by the main radiation directions of radiators in which the phase difference of the feed phases decreases with increasing frequency.

This invention makes it possible to produce radiation patterns which exhibit over a greater frequency range smaller field strength fluctuations, whereby the non-circularity of the radiation pattern can be reduced within a given band width, and wherein the transmitted frequency range can be extended in the presence of given non-circularity of the radiation diagram. These advantages are obtained in connection with omnidirectional radiation diagrams as well as in connection with sector-like radiation diagrams.

It may be mentioned at this point that antenna arrangements are known which are fed in a rotary field, that is, wherein the radiators, which are arranged on the sides of a square mast, are respectively rotated by a definite angle which is, however, identical for each radiator. Such an antenna arrangement is likewise narrowband, so far as the transmissible frequency range is concerned, since the angles between the main radiation directions of the individual radiators, even after the rotation, are always the same, there being in the disposition thereof no further consideration with respect to the phase conditions in the sense of the present invention.

The invention can be applied to omnidirectional antennae having a greater number (n) of radiators fastened in polygon arrangement on a mast or the like. In this instance the phase differences between the individual radiators correspondingly amount to $360/n$ degrees, in a manner so as to provide for an angle embraced by the main radiation directions of successively placed radiators, which is with increasing phase difference at increasing frequency, in excess of $360/n$ degrees. Conversely, the angles between the main radiation directions of successive radiators which result with increasing frequency in decreasing phase differences, are correspondingly selected so as to be smaller than $360/n$ degrees.

In connection with antennae operating with phase shifts of 180° or more, which is as a rule the case with antennae arrangements which are fed in a rotary field, the phase shifts of 180° are appropriately produced by changing the polarity of the feed lines of the respective radiators, while phase shifts greater than 180° are produced by change of polarity and further measures, for example, by insertion of cable portions of appropriate length. This measure permits further improvement in the uniformity of the radiation diagram.

It is in accordance with another feature of the invention possible to achieve a radiation diagram which exhibits even greater broadband uniformity, by carrying out the spatial displacement of the radiators, which serves to equalize distortions caused by the different phases. This will provide a spacing between those radiation center points at which the difference of the feed phases increases with increasing frequency, which spacing is greater than that provided between the radiators in which an increasing frequency causes a decrease of the difference of the feed phases.

However, in connection with known antenna arrangements operated to equalize the phase shift with spatially displaced radiators, the spatial displacement of the radiators is so effected that the spacing of the radiation center points remains approximately the same ahead of and in back of the displacement. The non-uniform spacings of the radiation center points result in more uniform radiation diagrams over a greater frequency range, making it possible to obtain, at constant band width, a slight non-circularity of the radiation diagram, while the transmissible frequency range is, with given non-circularity, extended. This results in the case of transmitter antennae, for example, for the radiation of television programs, in the advantage of making the reorientation of the antennae unnecessary incident to a change of channel within a band. The invention is in the same manner advantageously applicable in the case of sector-like radiation patterns and in the case of omnidirectional radiation diagrams.

A further improvement, in the sense of a more uniform broadband radiation pattern, can be obtained by referring the spatial displacement of the radiators, which serves to compensate or compensation for distortions caused by the different phases, of frequencies lying above the center frequency of the frequency band which is to be transmitted. The amount of the spatial displacement, known as such, of the radiators referred to the center frequency, is normally selected so that there is effected in the direction of the half angle line between the main radiation directions of two adjacent radiators, a superposition of radiation pattern in identical phase. However, the radiation pattern of an antenna arrangement, obtained in this manner, at greater deviations from the center frequency, exhibits stronger gaps or breaks which can be compensated in broadband manner, by appropriately smaller displacement. The center frequency is thereby determined by the condition which requires that the differences of the feed phases reach the values which are therefor desired. Accordingly, upon producing the phase differences by means of cable portions, the lengths of such portions are related to or referred to the wavelengths corresponding to the center frequency. In the case of antennae with

radiators arranged in a plane in a polygon and operating with rotary field feed, the difference between the feed phases amounts to $360/n$ degrees (which is the desired operating value).

Further details of the invention will appear from the description which is rendered below with reference to the accompanying drawings showing embodiments thereof.

FIG. 1 shows an antenna arrangement fed with the same phase;

FIG. 2 indicates an omnidirectional antenna with individual radiators which are rotated in the respective main radiation direction thereof;

FIG. 3 represents an omnidirectional antenna with different spacing of the radiation center points;

FIG. 4 illustrates an omnidirectional antenna with different spacing of the radiation center points and with the radiators rotated in the respective main radiation direction;

FIG. 5 indicates an antenna with spatially displaced radiators for compensating the phase differences;

FIG. 6 shows an antenna with slight spatial displacement of the radiators; and

FIG. 7 is a perspective view of a radiator group comprising two dipole fields.

The antenna shown in FIG. 1 comprises two radiators or radiator groups 2 and 3 which are arranged on two sides of a mast 1, the radiators being in this case constructed as full wave dipoles and being disposed in front of a reflector wall respectively indicated at 4 and 5. The radiation center points of the respective radiators are indicated by numerals 6 and 7, such center points lying symmetrically with respect to the terminal points of the radiators and in the region between these terminal points and the respective reflector wall 4 and 5. Antennae arrangements of this kind are known and are used especially in cases in which the feed of the individual radiators is effected with the same phase. Upon feeding the radiators with different phase signals, for improving the matching of the signals, there will be obtained a radiation pattern which differs from the one obtained when the signals are in the same phase, such different radiation pattern differing therefrom especially by having a different main radiation direction which lies approximately in the direction H.

In the arrangement indicated in FIG. 2, there are provided, on the sides of the mast 10, dipole fields 12, 13, 14 and 15 comprising respectively full wave dipoles disposed in front of a reflector wall. If the individual radiators are fed with the same phase (not shown), the dipole fields, corresponding in such case to the fields 12 to 15, are so arranged with respect to the mast that they lie symmetrically with respect to the individual sides of the mast, the longitudinal axes of the radiators thus extending parallel to the side planes of the mast 10. In the case of phase sifted feed signals in a rotary field, whereby there is a phase difference of $360/n$ degrees between the respective radiators, resulting with $n=4$ in 90 degrees, the radiators are, in known manner, shifted or displaced so that the distortions caused by the phase shifted signals are cancelled. In the arrangement illustrated in FIG. 2, there is for this purpose customarily applied a longitudinal displacement or shifting (along the side of the mast), amounting to $\lambda_m/4\sqrt{2}$. The wave length λ_m thereby corresponds to the frequency m , for which the difference of the feed phases between the radiators amounts exactly to $360/n$ degrees. The indicated shifting by $\lambda_m/4\sqrt{2}$ results, in the direction of the half angle line between the main radiation directions, in a displacement of $\lambda_m/4$, so that the radiations superpose in the same phase. The omnidirectional radiation pattern thereby obtained corresponds to the pattern of a radiator arrangement which is fed with signals of the same phase. The shifting or displacement of the individual radiator elements is thereby appropriately effected with reference to the radiation center points of the respective dipole field, the term

"radiation center point" indicating the point at which the radiator may be conceived as being concentrated in punctiform manner or, expressing it another way, the point from which the entire radiation is, for the remote field, radiated in an angular range as great as possible. This radiation center point lies in the illustrated antenna arrangements in the region between the radiators and the reflector wall midway between the radiator halves. The radiation center points of the illustrated dipole fields 12 to 15 lie, in the case of feed with the same phase at the points 16, 17, 18 and 19, symmetrically to the mast, while lying in the case of phase shifted feed (rotary field), at the points 20, 21, 22 and 23, owing to the spatial displacement effected for the compensation of the different phases. Upon transmission of greater frequency ranges, causing a deviation from the center frequency, there occur in this known kind of radiator arrangement deep breaks, valley separations, in the radiation pattern, the smallest values of $E/E_{\max}$, thereby lying at 0.5 for a frequency range of $f=0.85f_m$ to $f=1.18f_m$ (f_m =center frequency). The dipole fields 12 and 14 are for the broadband equalization of these breaks rotated by the angle α counter to the center rotation of the rotary field feed, the radiation center points 20 and 22 being thereby used as points of rotation. It is thereby assumed, for the feed of the individual radiator, that the phases 0° , 90° , 180° and 270° are respectively allocated to the dipole fields 12, 13, 14 and 15. These phase differences are appropriately produced by allocating to the dipole fields 12 and 14 feed cables of the same length, the dipole field 14 being thereby connected with opposite polarity. The leads to the fields 13 and 15 are shorter by $\lambda_m/4$ and the feed line to the fields 13 and 15 are likewise of opposite polarity. As a consequence, the differences of the feed phases between the fields 12 and 13 as well as between 14 and 15 increase with increasing frequency, while those between the fields 13 and 14 as well as between 15 and 12 decrease. Accordingly, the main radiation directions of the first named group of fields mutually embrace a greater angle than those of the second group. The displacement of the dipole fields 12 and 14, by the angle α , results in an omnidirectional radiation pattern with maximum breaks lying in the range $0.85f_m$ to $1.18f_m$, above the value $E/E_{\max}=0.5$.

In FIG. 3, there are arranged on the sides of a mast 31 the dipole fields 32, 33, 34 and 35 comprising respectively full wave dipoles disposed in front of a reflector wall. The radiation center points of the dipole fields are indicated at 36 to 39. As a radiation center point is designated the point at which the respective radiator or dipole field can be conceived as being punctiform concentrated of, expressed differently, at which the total radiation, considered for the remote field, is in the same phase radiated in an angular range which is as great as possible. Accordingly, the radiation center point lies in the illustrated radiator arrangement symmetrical to the respective radiator halves and in the range between the corresponding radiators and the reflector wall. In such an antenna arrangement with four radiator fields disposed on the sides of a square mast, there is normally made use of the rotary field feed, that is, there is provided a phase difference of 90° between the respective radiators. The phase step generally amounts in the case of n radiators disposed in a plane about a mast, to $360/n$ degrees. In order to equalize the breaks in the radiation diagram, which are caused by the different phases, the radiators are in known manner shifted along the sides of the mast, so that the radiation patterns of adjacent fields superpose again in phase between both radiators approximately in the region of the half angle line between the main radiation directions. A displacement along the sides of the mast, amounting for each radiator field to $\lambda/4\sqrt{2}$, results in the illustrated arrangement for a uniform spatial shifting. The spacings of the radiation center points remain thereby, in the known arrangements, after the shifting, constant,

such spacings corresponding approximately to the values such as are provided with feeding all radiators with the same phase. The positions of the radiation center points, resulting from signals of the same phase, are indicated by numerals 36, 40, 38 and 41, the connection lines between these points forming a square.

In the illustrated antenna arrangement, the feed of the radiators is effected by allocating to the dipole field 32 the phase 0° , to the dipole field 33 the phase 90° , to the dipole field 34 the phase 180° and to the dipole field 35 the phase 270° . It is thereby assumed that the feed phase of 180° , for the dipole field 34, is produced by change of polarization of the feed lines and that feed cables of the same length are provided for the fields 32 and 34. The feed cables for the fields 33 and 35 are shorter by $\lambda/4$ and the connections for the field 35 are additionally of changed polarity. As a consequence, the phase difference between the dipole fields 32 and 33 will become greater than 90° at a frequency which is higher than the center frequency f_m for which the cable lengths are designed, while the phase difference between the dipole field 33 and the dipole field 34 assumes correspondingly smaller values, since the phase angle of 180° for the dipole field 34 is produced by change of polarity, therefore being independent of the frequency. The phase difference between the dipole field 34 and the dipole field 35 becomes progressively greater than 90° , while the phase difference between the dipole field 35 and the dipole field 32 becomes progressively smaller than 90° .

Upon arranging the radiators in the heretofore customary manner, with the radiation center point constant at about λ_m , there will result breaks in the radiation diagram going in the range of 0.85 to $1.15f_m$, down to a value $E/E_{\max}=0.5$. The transposition or displacement of the radiation fields, so that the spacing of the radiation center points of the dipole fields is increased with increasing phase difference between the radiators and correspondingly decreased with decreasing phase differences, results in the illustrated radiation pattern in which the maximum breaks at the same frequency range go only down to the values $E/E_{\max}=0.56$, as seen in FIGURE 3. The spacing d_1 between the radiation center points 36 and 37 as well as the radiation center points 38 and 39 thereby amounts to about $1.25\lambda_m$, while the spacing d_2 respectively between the points 37, 38 and 39, 36 amounts only to $0.75\lambda_m$. The radiation diagram is plotted for the various frequencies, the full line curve 42 indicating the course at $f=f_m$, the dash line curve 43 the course at $f=0.85f_m$ and the dot-dash curve 44 the course at $f=1.18f_m$.

The change of position of the radiators can be effected in various ways, for example, by shifting both or only one of adjacent radiators. The displacement of the radiation center points for the illustrated radiation pattern amounts to about $\lambda_m/4$, in the direction of the angle half line between the main radiation directions, where λ_m corresponding to the center frequency f_m . A further improvement in the uniformity of the radiation pattern is obtained upon making this displacement smaller than $\lambda_m/4$. Expressed in other words, this means, that the displacement is referred to a frequency which is higher than f_m .

FIG. 4 shows an antenna arrangement for producing an omnidirectional radiation diagram, comprising dipole fields 51, 52, 53, 54 disposed on the sides of a square mast 50, said dipole fields consisting respectively of full wave dipoles arranged in front of a reflector wall. The radiation center points of the dipole fields are indicated by numerals 55, 56, 57 and 58, it being assumed that the feed of the radiators is effected in the manner explained in connection with FIG. 1 and that the phase 0° is allocated to the dipole field 51, the phase 90° to the dipole field 52, etc. The dipole fields 51 and 53 are, as described with reference to FIG. 1, in the main radiation directions thereof rotated by the angle α with respect to the sense of rotation of the rotary field, thereby provid-

ing the improvement of the radiation diagram explained in connection with FIG. 1. The spatial displacement or shifting with respect to the side planes of the mast is differently effected in addition to the rotation of these dipole fields. This results in different spacing between the radiation center points of the individual dipole fields, the spacing d_1 between the radiation center points of the dipole fields 51, 52 and 53, 54, respectively, and the spacing d_2 between the radiation center points of the dipole fields 52, 53 and 54, 51, being so selected that $d_1/d_2=1.15$. The selection of these different radiation center point spacings is governed by the rule according to which greater radiation center point spacings are provided for phase differences which increase with increasing frequency, while smaller spacings are provided for those radiation center points between which the phase difference becomes smaller with increasing frequency.

Based upon the mode of feed of the radiators, to be presently described with reference to FIG. 5, the phase difference between the dipole fields 51, 52 and 53, 54 becomes greater with increasing frequency, while smaller phase differences appear, between the dipole fields 52, 53 and 54, 51 with increasing frequency. The spatial displacement of the radiation center points or the shifting thereof along the sides of the mast provides an improvement of the omnidirectional radiation pattern, which is less than in the known arrangements. The displacement is normally so effected that the radiation of the individual dipole fields superpose approximately with the same phase, approximately in the region of the half angle line between the dipole fields at the center frequency f_m . This results, for example, in the case of square masts and dipole fields fed in rotary field with 90° phase difference, in a displacement along the sides of the mast, amounting to $\lambda_m/4 \cdot \sqrt{2}$. With reference to the half angle line, there is obtained a total displacement amounting to $0.25\lambda_m$. However, for obtaining a more uniform broadband omnidirectional radiation pattern, there is in the present case effected a displacement amounting only to $0.22\lambda_m$. Expressed in other words, this means, that the frequency corresponding to the spatial displacement of the radiation center points is approximately $1.14f_m$ and not the center frequency f_m . The angle for the rotation of the main radiation directions of the dipole fields 51 and 53 amounts to 5° .

The resulting radiation diagram is for various frequencies likewise represented in FIG. 4 in conjunction with the antenna arrangement. The full line curve 59 shows the course of the field strength for the frequency $0.85f_m$, the dash line curve 60 indicating the course for the frequency f_m , and the dot-dash curve 61 representing the course for the frequencies $f=1.18f_m$. Considerably shortened full wave dipoles with a ratio of length to diameter of about 15, disposed in front of a reflector wall, were used in the illustrated antenna arrangement. Accordingly, as compared with customarily constructed antenna, fed in a rotary field and having spatially simply displaced radiators, the deepest breaks of which extend for the same frequency range up to the value $E/E_{\max}=0.5$, there is obtained a considerably more uniform field strength curve, making it possible to transmit with the antenna arrangement and given non-circularity of the radiation diagram, a greater frequency range.

As illustrated in FIG. 7, in order to obtain a sharply focused vertical characteristic, a plurality of dipole fields 12' may be arranged, in known manner, in vertical succession in front of a reflector wall 4' to form a radiator group, thereby employing in the vertical direction the measures utilized as described in connection with the horizontal direction.

Referring to the arrangement shown in FIG. 5, it is assumed that the radiator 62 is fed with advancing phase as compared with the radiator 63. For the equalization of this phase difference, there is used in known manner

a spatial displacement of the radiators, such that the amount of the spacing d of the radiation center points in the direction H of the half angle line between the main radiation direction of the individual radiators 62 and 63, corresponds to phase difference expressed in terms of wave length. Accordingly, when the two radiators 62 and 63 are fed with a 90° phase difference, the spatial displacement will amount to $d=\lambda/4$. Upon maintaining the spacing D of the radiation center points perpendicularly to the main radiation direction, this antenna arrangement will have the same base width as the arrangement shown in FIG. 1 and therefore will result substantially in the same radiation diagram except for negligible alterations in the side fractions of the radiation. Upon transmitting a wider frequency band, the spacing d of the radiation center point was so selected, that the phase shift between the radiators, with reference to the center frequency f_m , was cancelled by the spatial displacement. As compared with this, the invention provides for a spatial displacement, such that the spacing d corresponding to a wave length which, in turn, corresponds to a frequency lying above the center frequency of the frequency band to be transmitted. Expressed in terms of length, this means that the spacing d is to be smaller than in case of the customary matching to the center frequency.

FIG. 6 shows an antenna arrangement for omnidirectional radiation and the corresponding radiation pattern for various frequencies. This antenna arrangement was constructed with shortened full wave dipoles with a ratio of length to diameter of about 15, with the respective dipoles disposed by about $0.28\lambda_m$ in front of planar reflectors. The spacing D between the radiation center points 70, 71, 72, 73 of the full wave dipole fields 74, 75, 76, 77, corresponded approximately to the wave length λ_m of the center frequency of the frequency range which is to be transmitted. The feed of the dipole fields 74 to 77 was effected with the phase 0° for the field 74, 90° for the field 75, the phase 180° for the field 76 and the phase 270° for the field 77. In the case of n fields, there generally applies for the phase step $\Delta\varphi$ from one to the other radiator, the relation $\Delta\varphi=360/n$ degrees. Feed cables of identical length were, for the production of the phase steps, assigned to the dipole fields 74 and 76 and the terminal points at the field 76 were changed in polarity (corresponding to the 180° phase difference). The leads for the fields 75 and 77 were shorter by $\lambda_m/4$ than those for the fields 74 and 76, and the polarity for the field 77 was additionally changed. These lengths correspond to the center frequency f_m . Upon shifting the radiation center points so that the resultant spatial displacement amounts, for the equalization of the phase shift at the center frequency in the direction of the half angle line, to $\lambda_m/4$, there will be obtained a radiation pattern with border values lying between $E/E_{\max}=1.0$ and $E/E_{\max}=0.5$. Upon using for the production of the phase shifts, in place of the described feed mode, cable portions of $\lambda_m/4$, $\lambda_m/2$ and $3\lambda_m/4$, that is, without change of polarity, there will be reached at the deepest breaks in the radiation diagram even values extending down to $E/E_{\max}=0.4$. The given values apply with the assumption that the transmitted frequency range lies between $f=0.85f_m$ and $f=1.18f_m$, whereby f_m corresponds to the center frequency formed by the geometric mean of the highest and lowest frequency of the frequency range which is to be transmitted.

As contrasted with this, the illustrated radiation pattern show the direction of the field strength resulting upon shifting the dipole fields by only 0.77 times the value which corresponds to a displacement referred to the center frequency f_m . In terms of the wave length, this means, that the frequency to which is referred the spatial displacement, has the value $f_m/0.77=1.3 \cdot f_m$. Accordingly, the spatial displacement of the radiators is in case of the illustrated antenna arrangement referred to a frequency which is outside the frequency range to be transmitted,

which frequency reaches in the present case its upper limit at $f=1.18f_m$. In the illustrated radiation pattern, the full line curve 78 corresponds to the frequency $f=0.85f_m$, the dash line curve to $f=f_m$ and the dot-dash curve 80 to $f=1.18f_m$. In the illustrated antenna arrangement according to the invention, the maximum breaks therefore lie above the value $E/E_{max}=0.5$ which results as the deepest break in the case of a displacement referred to the center frequency and operating with the same mode of feed.

The invention is not inherently limited to the described and illustrated antennae arrangements but may likewise be applied in cases of larger or smaller numbers of radiators disposed on a mast. Moreover, in the case of plural tier antenna arrays, there may be used a mechanical rotation of two respective superposed omnidirectional units, by 90° , with corresponding phase shifted feed. The shifting or displacement of the radiator elements, in a horizontal plane, may be analogously applied in the case of vertically stacked radiators fed with different phase, so as to obtain vertical radiation diagrams which likewise are to be as uniform as possible in a greater frequency range.

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 antenna arrangement having a relatively circular radiation pattern in the transmission range, comprising at least three radiators which are fed with different phasing and enclose, in the base arrangement, respective angles between their main radiation directions, in which between one radiator pair, on a change in the frequency, there occurs an increase, and between another radiator pair a decrease in the difference in the feed phases, the angles between the main radiation directions of adjacent radiators being such that radiators, between which the difference in the feed phases becomes greater with increasing frequency, enclose a greater angle between their main radiation directions than those radiators between which the difference in the feed phases becomes less with increasing frequency.

2. An antenna arrangement according to claim 1, having n -number of radiators fed in progressive phasing, for the production of an omnidirectional radiation diagram, wherein the radiators at which the phase differences increase with increasing frequency form with their main radiation directions an angle greater than $360/n$ degrees, the angle between the main radiation directions of radiators between which the phase difference decreases with increasing frequency, being smaller than $360/n$ degrees.

3. An antenna arrangement according to claim 1, wherein the phase shifting is, upon using phase angles of 180° , obtained by change of polarity of the feed, and in

case of greater phase angles additionally by the use of cable portions of appropriate length.

4. An antenna arrangement according to claim 1, wherein distortions of the radiation diagram, caused by different phases, is compensated by spatial displacement of the radiators, such that the spacing between those radiation center points the phase difference of which increases with increasing frequency, is greater than in the case of radiators at which an increasing frequency causes reduction of the phase difference.

5. An antenna arrangement according to claim 1, wherein the spatial displacement of the radiators is referred to a wave length which corresponds to a frequency lying above the center frequency of the frequency band which is to be transmitted.

6. An antenna arrangement according to claim 3, wherein the length of cable portions employed for the phase shifting is related approximately to the center frequency of the transmitted frequency range, thereby effecting at such frequency the desired distribution of the phase differences between the respective radiators.

7. An antenna arrangement according to claim 1, wherein the radiators are combined to form radiator groups at the respective inputs of which appear the desired phase relations.

8. An antenna arrangement according to claim 1, forming an omnidirectional antenna, comprising radiators uniformly disposed about a mast and fed with a rotary field.

9. An antenna arrangement according to claim 4, comprising four dipole fields disposed at the sides of a square mast, the spacing between adjacent radiation center points d_1 and d_2 lying approximately at $d_1/d_2=1.15$.

10. An antenna arrangement according to claim 4, for transmitting a band width of about 0.85 to $1.18f_m$ (f_m =center frequency), wherein the spatial displacement of the radiators is referred to a wave length corresponding to a frequency $1.14f_m$.

11. An antenna arrangement according to claim 4, comprising four radiators disposed on the sides of a square mast and fed in a rotary field, wherein the deviation from the angle between main radiation directions, given by the requirement $360/n$ degrees (n =number of radiators), amounts respectively to 5° .

12. An antenna arrangement according to claim 4, wherein the rotation of the radiators is effected about the radiation center point as an axis of rotation.

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ELI LIEBERMAN, *Primary Examiner*.