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(54) A METHOD OF FEEDING AN ANTENNA ARRAY AND FEEDING ARRANGEMENT OF THE ANTENNA ARRAY

(57) A method of feeding an antenna array, wherein the pattern similar to the cosecant pattern is achieved, according to the invention, characterized in that the consecutive radiators (RAD) are fed alternately with a positive and negative phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1). Additionally, at least once two adjacent phase differences (from a set of F2-F1, F3-F2, F4-F3,..., FN-FN-1) at least once have the same direction of change, all the phases (F1, F2, F3, F4, ..., FN) being normalized to a range from 0° to 360°.

An antenna array feeding arrangement, comprising an array of radiators, according to the invention, characterized in that it comprises at least 8 radiators (RAD). Consecutive radiators (RAD) are fed alternately with a positive and negative phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1) and at least two adjacent phase differences (from a set of F2-F1, F3-F2, F4-F3,..., FN-FN-1) at least once have the same direction of change, all the phases (F1, F2, F3, F4, ..., FN) being normalized to a range from 0° to 360°.

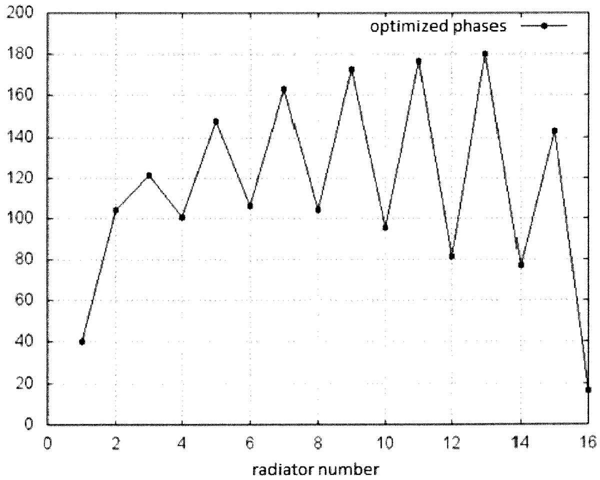

Fig. 7

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Description

[0001] The object of the invention is a method of feeding of the antenna array, in particular antenna array with cosecant vertical radiation pattern for radio communication, radar and radiolocation networks, including mobile network and radar station antennas. The object of the invention is also an antenna array feeding arrangement, in particular an antenna array with a cosecant pattern.

[0002] In radiocommunication systems, in the known solutions of transmitting antennas, including base stations and radars, the aim is to achieve a constant level of transmitted signals in the coverage area. Such a requirement is met if the antenna has a cosecant vertical radiation pattern. This is achieved by shaping the vertical radiation pattern, for example by filling their nulls and flattening side lobes maxima. So far achieved vertical antenna radiation patterns, however, are far from ideal cosecant patterns.

[0003] Most of today's transmitting/receiving antennas have an antenna array structure consisting of several radiators, generally half-wave dipoles. The base station antennas usually have radiators disposed in one vertical column, not necessarily on the same vertical axis, at distances substantially equal to half of the wave-length λ. There are also base station antennas that have a dominant linear system, consisting of multiple levels, and at each level there are several radiators, generally much fewer than the number of levels of the antenna array.

[0004] Other antennas, such as of radars, have radiators arranged on a plane, both horizontally and vertically, with a similar number of radiators in each of the two dimensions. Then each column of radiators can have cosecant vertical radiation pattern.

[0005] Each of the radiators of the antenna array can operate in a horizontal, vertical or slant polarisation. Recently, slant polarisation + 45° and -45° has become more important. Radiators grouped in pairs may also operate in elliptical polarisation, and in particular in circular polarisation.

[0006] Shaping a vertical radiation pattern of the antenna array, for instance, to obtain cosecant pattern, may take place substantially in two ways:

- by irregularities in the geometrical arrangement of radiators and
- by suitable distribution of amplitudes and phases in feeding arrangement.

[0007] In practice, the easiest way is to implement the diversity of phases that feeding radiators , and then - with some limitations - changes in the amplitude of currents feeding radiators. In practice irregularities in the distribution of the radiators are also used, but irregularities are limited, for example, the distances between the radiators are substantially equal to half a wave-length, but there may be two or three close to half the wave-length of this distance, generally used alternately.

[0008] Interesting possibilities of shaping the pattern is created by a combination of two above-mentioned methods, i.e. use of irregularities in the distribution of the radiators, and appropriate selection of phases, and possibly also the amplitudes.

[0009] Patent application GB 1186786 A discloses a solution wherein a high frequency or ultra high frequency antenna comprises a plurality of antenna elements which are arranged on multiple levels and which are supplied with the same amplitude. This antenna contains four units of substantially the same size, placed at the centre of the antenna, one above the other, each of which has two levels of radiators of different phases. In this solution, vertical radiation pattern is shaped in the direction of a cosecant pattern through appropriate distribution of antenna array excitation phases. Increments in excitation phases are limited to a maximum value of 100° and are divided into a 4-step procedure for the consecutive, different groups of levels. The resultant one excitation phase distribution is unique for a given number of levels of the antenna system, and provides a vertical pattern, which is somewhat similar to a cosecant pattern.

[0010] Patent application JP 2000082920 A discloses a two-dimensional antenna array with a symmetrical radiation pattern in the horizontal plane and a cosecant pattern in the vertical plane. Radiation level from the power supply system was reduced by its appropriate shaping. The individual antenna elements are supplied with diverse amplitudes and phases. Changes in various phases of antenna elements consist of a sequence alternating with a number of positive increments and then multiple negative increments.

[0011] Patent application US004766437A discloses an antenna system, consisting of two antenna systems with multiple antenna elements, excited with exponential amplitudes. The input signal supplies both antenna assemblies with the same amplitude and phase. Individual antenna elements in both antenna assemblies are supplied with amplitudes with exponentially changing values. Phase shifter allows the selection of phases between the two antenna systems. When its value is between 60° and 120°, then the pattern has a cosecant shape.

[0012] Patent application US 006107964 A presents a method of obtaining a cosecant pattern in the slot antenna through appropriate pattern of amplitudes and phases distribution. Amplitude distribution of the consecutive radiators varies linearly. Relative phase distribution also changes linearly, except for the first radiator, which is fed with a defined pitch phase.

[0013] Patent application EP 2434577 A1 discloses a solution, wherein an antenna arrangement for providing direct air - ground communication, includes an antenna array with multiple antenna elements, preferably in a linear configuration and the feeding network with multiple antenna lines energizing multiple antenna elements with the RF signal. The feeding network is adapted to generate phase shifts and different amplitudes in antenna paths, so that the antenna array provides an approximation of the target pattern of the antenna array gain, in particular the approximation of a cosecant pattern in the plane of elevation for elevation angles from the elevation limit angle with the maximum gain to the elevation angle of 90°. In the disclosed solution an antenna array has a shaped vertical upward radiation pattern (from the base station towards the aircraft), wherein the pattern has an optimized shape for a cosecant pattern using numerical optimization.

[0014] In all the above solutions vertical radiation pattern of transmitting antennas, composed of the radiators, are far from a perfect, cosecant radiation pattern. As a result, in a service area the level of transmitted and received signals is still characterized by relatively high volatility, i.e. still there are places with poor reception of transmitted signals.

[0015] The proposed solution related to the method of feeding of the antenna array and antenna array feeding arrangement allows for gaining the radiation pattern very close to the ideal cosecant pattern, thus the level of transmitted and received signals across the service area is much more stable and much less dependent on the distance from the transmitting station. The solution allows gaining a much more uniform distribution level of transmitted or received signals compared to current solutions. The existing antenna array feeding methods are not able to provide such a uniform level of transmitted or received signals.

[0016] A method of feeding an antenna array, according to the invention, wherein normalized relative phases of consecutive radiators of the array are diverse and the pattern is achieved similar to the cosecant pattern, is characterized by the fact that the consecutive radiators are fed alternately with a positive and negative phase difference, and at least two adjacent phase differences at least once have the same direction of change, all the phases being normalized to a range from 0° to 360°.

[0017] Preferably, the same direction of phase change of adjacent radiators is achieved by feeding the radiators with a positive phase difference.

[0018] Preferably, the same direction of phase change of adjacent radiators is achieved by feeding the radiators with a negative phase difference.

[0019] Preferably, radiators are fed with a variable amplitude of phase difference.

[0020] Preferably, radiators are fed with the same excitation amplitude.

[0021] Preferably, radiators are fed with a different excitation amplitude.

[0022] Preferably, at least 8 radiators are arranged at intervals between about half the wave-length.

[0023] An antenna array feeding arrangement, according to the invention, comprising an array of radiators, is characterized by the fact that it comprises at least 8 radiators, wherein the consecutive radiators are fed alternately with a positive and negative phase difference, and at least two adjacent phase differences at least once have the same direction of change, all the phases being normalized to a range from 0° to 360°.

[0024] Preferably, adjacent radiators with phase changes with the same direction are fed with a positive phase difference.

[0025] Preferably, adjacent radiators with phase changes with the same direction are fed with a negative phase difference.

[0026] Preferably, radiators are fed with a variable amplitude of phase difference. Preferably, radiators are fed with the same or different excitation amplitude.

[0027] Preferably, radiators are arranged at intervals of approximately half wave-length between them.

[0028] Preferably, array of radiators comprises 16 radiators.

[0029] Preferably, array of radiators comprises an even or odd number of radiators.

[0030] Application of the proposed solution related to a method of feeding of an antenna array and antenna array feeding arrangement will allow a much better and more balanced coverage area served by the base station, which will also enable optimization of broadcast network and obtained parameters, including the elimination of some microcells completing the gaps in the coverage ranges. For radars a solution will significantly increase the accuracy of the location of the tracked objects, that is, information about the location of the objects.

[0031] The application of the proposed solution by the operators of cellular and radiocommunication systems will make it possible to achieve even coverage of the transmitted and received signals throughout the service area. This will minimize existence and extent of the areas with too low signal level or lack thereof, and aligns the level of the signals received.

[0032] The object of the invention is shown in the drawing, in which

fig. 1 presents a schematic view of an AN antenna array (assembly) feeding arrangement,

fig. 2 - a schematic view of AN antenna assemblies of 8, 16 and 24 levels (bays) with RAD radiators in vertical polarisation,

fig. 3 - a schematic view of AN antenna assemblies of 8, 16 and 24 levels (bays) for two frequencies f and 2f and

two +45° i -45°polarisations,

fig. 4 - a system of phases distribution F1, F2, F3, F4, ..., FN for an AN antenna array with 8 RAD radiators.

fig. 5 - comparing the vertical radiation pattern of the homogeneous system, with all the phase differences equal to 0°, ideal cosecant pattern and the resulting pattern of an AN antenna array with 8 RAD radiators,

fig. 6 - field strength distributions as a function of distance from the antenna mast (tower), normalized relative to the maximum value for an AN antenna array with 8 RAD radiators, excited with 0° phases (dashed line) and the phases of fig. 4 (solid line),

fig. 7 - a system of phases distribution F1, F2, F3, F4, ..., FN for an AN antenna array of 16 levels with RAD radiators.

fig. 8 - comparing the vertical radiation pattern of the homogeneous system, ideal cosecant pattern and the resulting pattern of an AN antenna array with 16 RAD radiators,

fig. 9 - field strength distributions as a function of distance from the antenna mast, normalized relative to the maximum value for an AN antenna array with 16 RAD radiators, excited with 0° phases (dashed line) and the phases of fig. 7 (solid line),

fig. 10 - a system of phases distribution F1, F2, F3, F4, ..., FN for an AN antenna array of 24 levels with RAD radiators.

fig. 11 - comparing the vertical radiation pattern of the homogeneous system, ideal cosecant pattern and the resulting pattern of an AN antenna array with 24 RAD radiators,

fig. 12 - field strength distributions as a function of distance from the antenna mast, normalized relative to the maximum value for an AN antenna array with 24 RAD radiators, excited 0° phases (dashed line) and the phases of fig. 10 (solid line).

[0033] A method of feeding an AN antenna array of fig. 1 consists in feeding N consecutive RAD radiators with any polarisation, arranged at intervals about half the wave-length ($\lambda/2$) there between, alternately with a positive and negative phase difference F2-F1, F3-F2, F4-F3,..., FN-FN-1. In order to obtain a cosecant pattern at least once two adjacent phases differences from a set of F2-F1, F3-F2, F4-F3,..., FN-FN-1 have the same direction of change, all the phases F1, F2, F3, F4, ..., FN being normalized to a range from 0° to 360°. It means that the sequence of alternating change of relative phase F1, F2, F3, F4, ..., FN is disturbed by introducing at least one monotonic change sequence of the phase F1, F2, F3, F4, ..., FN of at least two consecutive RAD radiators.

[0034] In the case of a smaller number of levels (for example 8 levels) such interference occurs singly and occurs at one of the ends of the AN antenna array. In the case of a larger number of levels (e.g. 16 levels) in the AN antenna array there may be several sections of the oscillating change of phase differences F1-F2, F3-F2, F4-F3, ..., FN-FN-1, preferably, each of these sections has different amplitudes of changes (larger, smaller, etc.), and the sections are separated by a monotonic change in two consecutive differences of the phases from a set of F1-F2, F3-F2, F4-F3, ..., FN-FN-1.

[0035] Differences of phases F2-F1, F3-F2, F4-F3,..., FN-FN-1 as to the absolute value are not the same, in other words, the change amplitude of the relative phases F1, F2, F3, F4, ..., FN between consecutive RAD radiators is not the same, although an embodiment is possible with the same amplitude of differences of phases F2-F1 F3-F2, F4-F3, ..., FN-FN-1. The excitation amplitudes A1, A2, A3, A4, ..., AN are preferably the same, but embodiments are possible with different excitation amplitudes A1, A2, A3, A4, ..., AN.

[0036] RAD radiators of the AN antenna array may operate in any polarisation. A solution according to the invention can be applied to any AN antenna array with RAD radiators disposed in the AN antenna array.

[0037] A method and system of feeding the AN antenna array according to the invention may apply to both the linear array (e.g. for cellular base station antennas) and vertical patterns of the planar array (e.g. radar antennas or base stations antennas with a number of beams in the horizontal plane).

[0038] In the embodiments described below a method and system of feeding the AN antenna array will be presented for the linear AN antenna array, positioned vertically, which is typical for cellular base station antennas. Other arrangement of RAD radiators and AN antenna array is possible. However, in any case, for each independent AN antenna assembly levels (bays) of radiators can be picked up and fed according to a proposed solution.

[0039] Presented method and feeding arrangement of the AN antenna array will allow to achieve a vertical radiation pattern in the AN antenna array of a shape close to a cosecant pattern. The applied solution can be used to achieve a radiation cosecant pattern required by the range of angles required by a given radiocommunication system (elevation and azimuth).

[0040] In the embodiments of the method and feeding arrangement of the AN antenna array presented in fig. 2, RAD radiators are arranged in a regular distribution in the vertical polarisation and arranged one above the other. It shows three embodiments, each with a different number of RAD radiators, with 8, 16 and 24 levels. In the preferred embodiment there should be an even number of RAD radiators, such as 10, 12, 14, 18, 20, 22, 26, etc. In other embodiments, AN antenna arrays with up to 72 or more RAD radiators are used. An odd number of RAD radiators is also permissible.

[0041] Fig. 3 presents the embodiments of the method and feeding arrangement of three linear AN antenna arrays with RAD radiators operating in two frequency ranges (f = 900 MHz and 2f = 1800 MHz) and two polarisations (+45° and -45°) at 8, 16 and 24 levels, respectively. Each of three embodiments of fig. 3 has generally 4 independent AN antenna arrays:

- an AN antenna array in +45° polarisation at frequency f (thin line, RAD radiators inclined to the right);
- an AN antenna array in -45° polarisation at frequency f (thin line, RAD radiators inclined to the left);
- an AN antenna array in +45° polarisation at frequency 2f (thick line, RAD radiators inclined to the right);
- an AN antenna array in -45° polarisation at frequency 2f (thick line, RAD radiators inclined to the left);

[0042] For each of 4 independent AN antenna assemblies independent vertical radiation pattern shaping is possible, but from a practical point of view in all cases, the most desirable is a cosecant pattern. In this embodiment differentiation of the geometrical arrangement of RAD radiators is used for each of 4 independent AN antenna assemblies, to some extent brought about by placing antennas at frequency f and 2f in the same location. In the case of the AN antenna array at frequency f, in a reproducible manner distances between the levels (bays) are changing every two levels. Also, the spacing of radiators from the vertical axis of the AN antenna array changes every second levels.

[0043] In the embodiment of the method and feeding arrangement of the AN antenna array of fig. 3 RAD radiators are arranged in a reproducible manner, at frequency f in 2 and at frequency 2f in 4 various configurations, in the AN antenna array for frequency f there are two alternating distances and in the AN antenna array for frequency 2f three sequentially repeating distances in the vertical direction. Furthermore, there is little separation of the RAD radiator position in the horizontal direction.

[0044] Basic vertical radiation pattern shaping for obtaining a cosecant pattern is performed by changing the phases F1, F2, F3, F4, ..., FN of individual levels of the AN antenna array. In the basic embodiment only the diversity of the phases F1, F2, F3, F4, ..., FN is applied, and the excitation amplitudes A1, A2, A3, A4, ..., AN are the same, but in other embodiments differentiated excitation amplitudes A1, A2, A3, A4, ..., AN may be used, resulting in a near-perfect compliance of obtained patterns with a cosecant pattern. Because mentioned embodiments apply presently typical geometry of AN antenna arrays with RAD radiators in -45° and +45° polarisations, fig. 3, so two independent AN antenna arrays are operating at frequency f, therefore also the geometry of distributing successive RAD radiators of each AN antenna array is not regular, in the strict sense.

[0045] Fig. 4 presents a pattern of phases F1, F2, F3, F4, ..., FN for AN antenna array composed of 8 levels with RAD radiators, for frequency f = 900 MHz and +45° polarisation. In figures with field strength distribution as a function of the distance from the antenna (fig. 6, 9 and 12) electrical means of AN antenna arrays are at a height of 25 m above ground level (agl), and the calculations were made at a height of 1.5 m above ground level. According to the method and feeding arrangement of the AN antenna array the levels are fed in order from the first level (lowermost) to the level 8 (highest), as follows:

Level 1: 10°;
Level 2: 67.9°;
Level 3: 95.8°;
Level 4: 63.9°;
Level 5: 125.6°;
Level 6: 56.1°;
Level 7: 124.7°;
Level 8: 19.0°;

[0046] In the embodiment of the method and feeding arrangement, the system of phases distribution F1, F2, F3, F4, ..., FN is alternating (positive and negative) and the differences of the phases F2-F1, F3-F2, F4-F3,..., FN-FN-1 between consecutive levels differ in amplitude. Additionally, there is one disturbance of the oscillating nature of changes of consecutive phase differences F2-F1, F3-F2, F4-F3, ..., FN-FN-1-between the levels 1 and 2 (F2-F1) and 2 and 3 (F3-F2) - the direction of changes is the same, in this case positive, which means that two consecutive phase differences F2-F1 and F3-F2, change monotonically (they are positive). Application of this method and feeding arrangement, allows obtaining the pattern close to a cosecant pattern, shown in fig. 5 and 6, wherein a pattern of the above-mentioned AN antenna array is almost identical to the ideal cosecant pattern, and the distribution of normalized field strength value (solid line in fig. 6) is close to the horizontal straight line. Due to relatively small number of RAD radiators (only 8) the pattern still deviates from the cosecant pattern, i.e. a horizontal line, however, variation of the field strength is considerably reduced.

[0047] Fig. 7 presents a system of phases distribution F1, F2, F3, F4, ..., FN for the AN antenna array comprising 16 levels with RAD radiators in +45° polarisation. This system corresponds to the middle panel of fig. 3. Half of RAD radiators, drawn thin line, inclined by 45° (in the figure similar to the mark "/") operated in +45° polarisation. Distances between individual levels are not the same (in this case, two different distances occur alternately). There is also the radiators shift in the horizontal plane (left and right of the vertical axis of the panel).

[0048] In the embodiment of the method and feeding arrangement, excitation amplitudes A1, A2, A3, A4, ..., AN of all RAD radiators are the same. Individual levels with RAD radiators are fed in order from the first level (lowermost) to the level 16 (highest), as follows:

Level 1: 40°;	Level 5: 147.9°;
Level 2: 104.5°;	Level 6: 106.5°;
Level 3: 121.3°;	Level 7: 163.0°;
Level 4: 101.0°;	Level 8: 104.4°;
Level 9: 172.2°;	Level 13: 180.1°;
Level 10: 95.8°;	Level 14: 77.4°;
Level 11: 176.6°;	Level 15: 142.8°;
Level 12: 81.9°;	Level 16: 16.4°;

[0049] In the embodiment of the system of phases distribution F1, F2, F3, F4, ..., FN phase differences F2-F1, F3-F2, F4-F3,..., FN-FN-1 are alternately positive and negative between consecutive levels, with variable amplitude of the differences, in the range of 20 to 120 degrees. At the same time, there is one disturbance of the oscillating nature of the phase differences F2-F1, F3-F2, F4-F3, ..., FN-FN-1- two consecutive phase differences between the levels 1 and 2, F2-F1 and 2 and 3, F3-F2, have the same direction of changes, in this case positive, which means that two consecutive phase differences F2-F1 and F3-F2 change monotonically (they are positive).

[0050] 3 remaining AN antenna arrays, may be excited in the same way, out of 4 AN antenna arrays, that may be performed at this antenna panel, i.e. RAD radiators in -45° polarisation (second half of RAD radiators marked with a thin line) and one and the other half of RAD radiators marked with a thick line (RAD radiators +45° "/" and RAD radiators -45° "\", respectively). In the case of RAD radiators marked a thick line operating frequency of the AN antenna array is essentially twice the operating frequency of the AN antenna array with RAD radiators marked with a thin line.

[0051] Application of this method and feeding arrangement, allows obtaining the pattern close to a cosecant pattern, shown in fig. 8 and 9, wherein a pattern of the above-mentioned AN antenna array is almost identical to the ideal cosecant pattern, and the distribution of normalized field strength value (solid line in fig. 9) is close to the horizontal straight line. Due to the increase in the number of RAD radiators (and thus the number of degrees of freedom), the resultant pattern is much closer to the cosecant pattern than in the case of the AN antenna array with 8 levels (fig. 6).

[0052] Another embodiment of the method and feeding arrangement is shown in fig. 10. It is the AN antenna array, comprising 24 levels with RAD radiators in +45° polarisation. Fig. 12 electrical means of AN antenna assemblies are at a height of 25 m above ground level, and the calculations were made at a height of 1.5 m above ground level. Individual levels with RAD radiators are fed in order from the first level (lowermost) to the level 24 (highest), as follows:

Level 1: 250°	Level 9: 114.9°	Level 17: 161.3°
Level 2: 80.6°	Level 10: 96.3°	Level 18: 79.0°
Level 3: 278.1°	Level 11: 135.9°	Level 19: 161.3°
Level 4: 85.0°	Level 12: 94.1°	Level 20: 60.5°
Level 5: 59.1°	Level 13: 144.7°	Level 21: 167.1°
Level 6: 97.4°	Level 14: 92.5°	Level 22: 64.2°
Level 7: 114.4°	Level 15: 153.9°	Level 23: 13.0°
Level 8: 83.1°	Level 16: 84.4°	Level 24: 3.4°

[0053] In the presented system of phases F1, F2, F3, F4, ..., FN one may note an oscillating nature (alternately positive and negative) of the phase changes F2-F1, F3-F2, F4-F3,..., FN-FN-1 of a greater amplitude of changes (150°-200°): levels 1 to 4, and a smaller amplitude of changes (40° to 120°): levels 5 to 24, separated by a monotonic nature of changes of phase differences, both phase differences F2-F1, F3-F2, F4-F3,..., FN-FN-1 between the levels 3 and 4, F4-F3 and 4 and 5, F5-F4 have a negative direction of changes and the immediately following two phase differences between levels 5 and 6, F6-F5, and 6 and 7, F7-F6 have a positive direction of changes.

[0054] Application of this method and feeding arrangement, allows obtaining the pattern close to a cosecant pattern, shown in fig. 11 and 12, wherein a pattern of the above-mentioned AN antenna array is almost identical to the ideal cosecant pattern, and the distribution of normalized field strength value (solid line in fig. 12) is close to the horizontal straight line. Due to the increase in the number of RAD radiators (and thus the number of degrees of freedom), the resultant pattern is much closer to the cosecant pattern than in the case of the AN antenna arrays with 8 and 16 levels (fig. 6 and 9).

[0055] Fig. 1 shows a feeding arrangement of the AN antenna array, comprising an array of RAD radiators, which comprises N of RAD radiators. A feeding arrangement of the AN antenna array is adapted to generate the differences of phases F2-F1, F3-F2, ..., FN-FN-1 between RAD radiators and also the excitation amplitudes A1, A2, ..., AN which can but do not need to be identical.

[0056] Consecutive RAD radiators are fed alternately with a positive and negative phase difference F2-F1, F3-F2, F4-F3,..., FN-FN-1, and two adjacent phase differences from a set of F2-F1, F3-F2, F4-F3,..., FN-FN-1 in at least one case have the same direction of change, all the phases F1, F2, F3, F4, ..., FN being normalized to a range from 0° to 360°. It means that the sequence of alternating change of relative phases F1, F2, F3, F4, ..., FN is disturbed by introducing at least one monotonic change sequence of the phase in the set of phases F1, F2, F3, F4, ..., FN for at least two consecutive RAD radiators.

[0057] In the case of a smaller number of levels (for example 8 levels) such interference occurs singly and most often is located at one of the ends of the AN antenna. In the case of a larger number of levels (e.g. 16 levels) in the AN antenna array there may be several sections of the oscillating change of phase differences F2-F1, F3-F2, F4-F3, ..., FN-FN-1, preferably, each of these sections has different amplitudes of changes (larger, smaller, etc.), and the sections are separated by a monotonic change in two consecutive differences of the phases from a set of F2-F1, F3-F2, F4-F3, ..., FN-FN-1.

[0058] Phase differences F2-F1, F3-F2, F4-F3,..., FN-FN-1 as to the absolute value are not the same, in other words, the change amplitude of the relative phases F1, F2, F3, F4, ..., FN between consecutive RAD radiators is not the same, although an embodiment is possible with the same amplitude of phase differences F2-F1 F3-F2, F4-F3, ..., FN-FN-1. The excitation amplitudes A1, A2, A3, A4, ..., AN are preferably the same, but embodiments are possible with different excitation amplitudes A1, A2, A3, A4, ..., AN.

[0059] In other embodiments a feeding arrangement comprises 16 or 24 levels with RAD radiators. In the preferred embodiment there should be an even number of RAD radiators, such as 10, 12, 14, 18, 20, 22, 26, etc. In other embodiments, AN antenna arrays with up to 72 or more RAD radiators are used. An odd number of RAD radiators is also permissible.

[0060] A method and feeding arrangement of the AN antenna array mentioned above may apply to both the linear array (e.g. for base station antennas) and the planar array (e.g. radar antennas or base stations antennas with a number of beams in the horizontal plane).

[0061] Two-dimensional AN antenna arrays are also possible: with the levels (columns) and lines. Then each column is an antenna subarray and proposed solution may be applied to each column (or only to the selected columns). Such a planar AN antenna array will be applied in radar technology (radar antennas).

Claims

1. A method of feeding an antenna array, wherein normalized relative phases of consecutive radiators of the array are diverse and the pattern is achieved similar to the cosecant pattern, **characterized in that** the consecutive radiators (RAD) are fed alternately with a positive and negative phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1), and at least two adjacent phase differences at least once have the same direction of change, all the phases (F1, F2, F3, F4, ..., FN) being normalized to a range from 0° to 360°.

2. Feed method according to claim 1, **characterized in that** the same direction of phase change (F1, F2, F3, F4, ..., FN) of adjacent radiators (RAD) is achieved by feeding the radiators (RAD) with a positive phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1).

3. Feed method according to claim 1, **characterized in that** the same direction of phase change (F1, F2, F3, F4, ..., FN) of adjacent radiators (RAD) is achieved by feeding the radiators (RAD) with a negative phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1).

4. Feed method according to claim 1, **characterized in that** the radiators (RAD) are fed with a variable amplitude of phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1).

5. Feed method according to claim 1, **characterized in that** the radiators (RAD) are fed with the same excitation amplitude (A1, A2, A3, A4, ..., AN).

6. Feed method according to claim 1, **characterized in that** the radiators (RAD) are fed with a different excitation amplitude (A1 A2, A3, A4, ..., AN).

7. Feed method according to claim 1, **characterized in that** at least 8 radiators (RAD) are arranged at intervals between about half the wave-length.

8. An antenna array feeding arrangement comprising an array of radiators, **characterized in that** it comprises at least 8 radiators (RAD), wherein the consecutive radiators (RAD) are fed alternately with a positive and negative phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1), and at least two adjacent phase differences at least once have the same direction of change, all the phases (F1, F2, F3, F4, ..., FN) being normalized to a range from 0° to 360°.

9. An antenna array feeding arrangement according to claim 8, **characterized in that** the adjacent radiators (RAD) with phase (F1, F2, F3, F4, ..., FN) changes with the same direction are fed with a positive phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1).

10. An antenna array feeding arrangement according to claim 8, **characterized in that** the adjacent radiators (RAD) with phase (F1, F2, F3, F4, ..., FN) changes with the same direction are fed with a negative phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1).

11. An antenna array feeding arrangement according to claim 8, **characterized in that** the radiators (RAD) are fed with a variable amplitude of phase difference (F2-F1, F3-F2, F4-F3,..., FN-FN-1).

12. An antenna array feeding arrangement according to claim 8 **characterized in that** the radiators (RAD) are fed with the same or with different excitation amplitude (A1, A2, A3, A4, ..., AN).

13. An antenna array feeding arrangement according to claim 8 **characterized in that** the radiators (RAD) are arranged at intervals of approximately half wave-length between them.

14. An antenna array feeding arrangement according to claim 8 **characterized in that** the array (AN) of radiators (RAD) comprises 16 radiators (RAD).

15. An antenna array feeding arrangement according to claim 8 **characterized in that** the array (AN) of radiators (RAD) comprises an even or odd number of radiators (RAD).

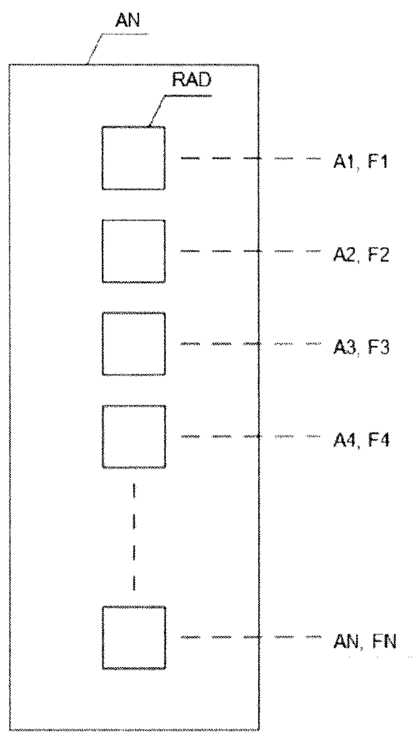


Fig. 1

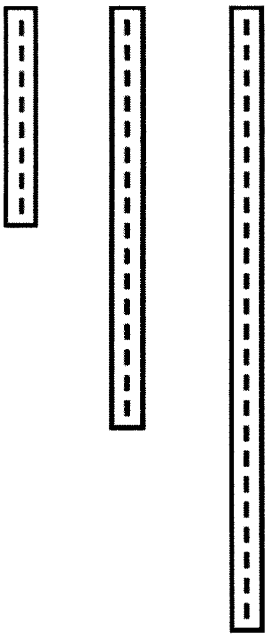


Fig. 2

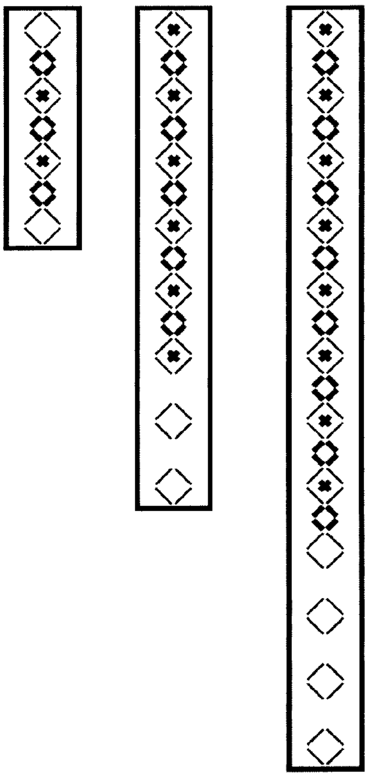
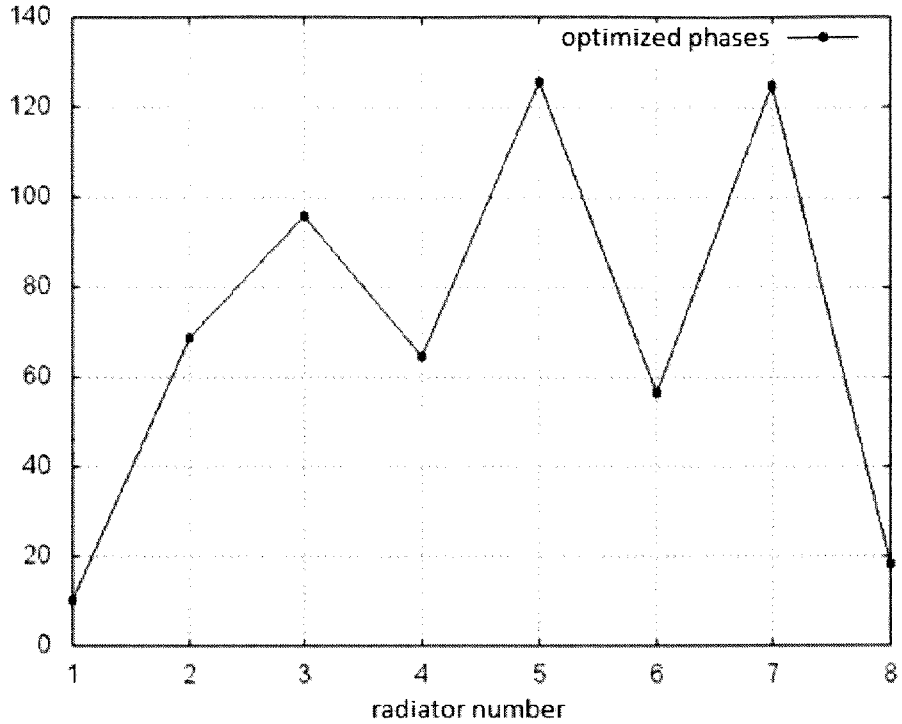
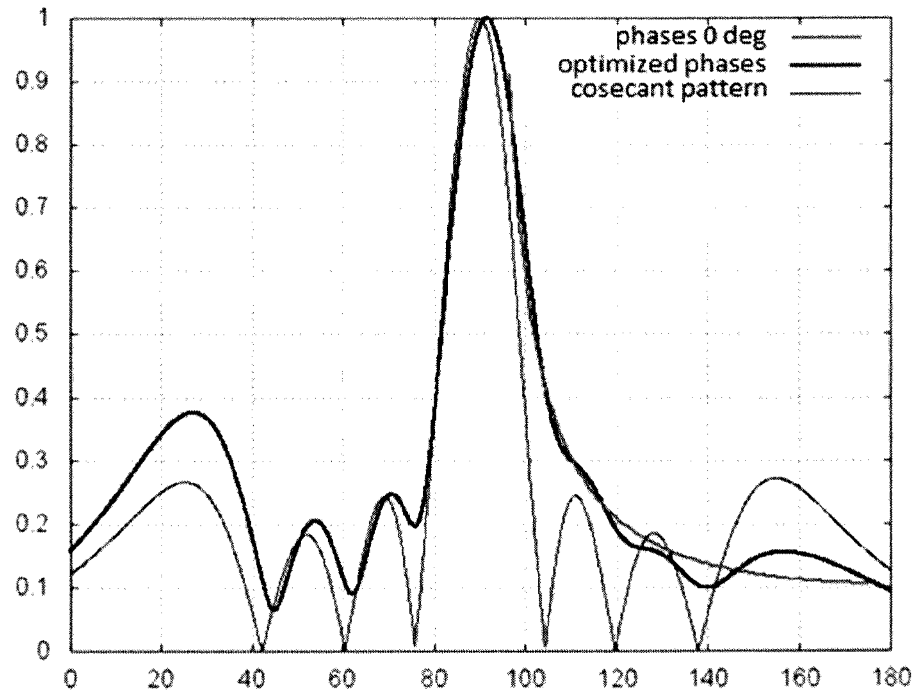


Fig. 3



optimized phases
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
radiator number

Fig. 4



phases 0 deg
optimized phases
cosecant pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
180

Fig. 5

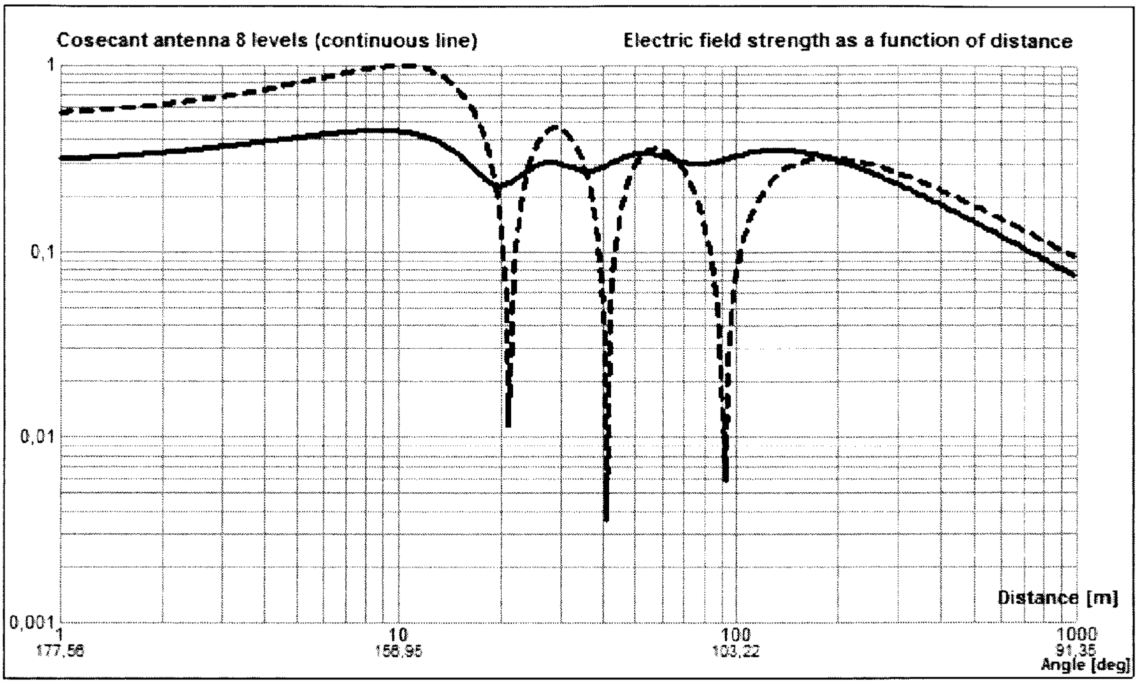

Cosecant antenna 8 levels (continuous line)
Electric field strength as a function of distance
1
0,1
0,01
0,001
1
177,56
10
156,95
100
103,22
1000
91,35
Distance [m]
Angle [deg]

Fig. 6

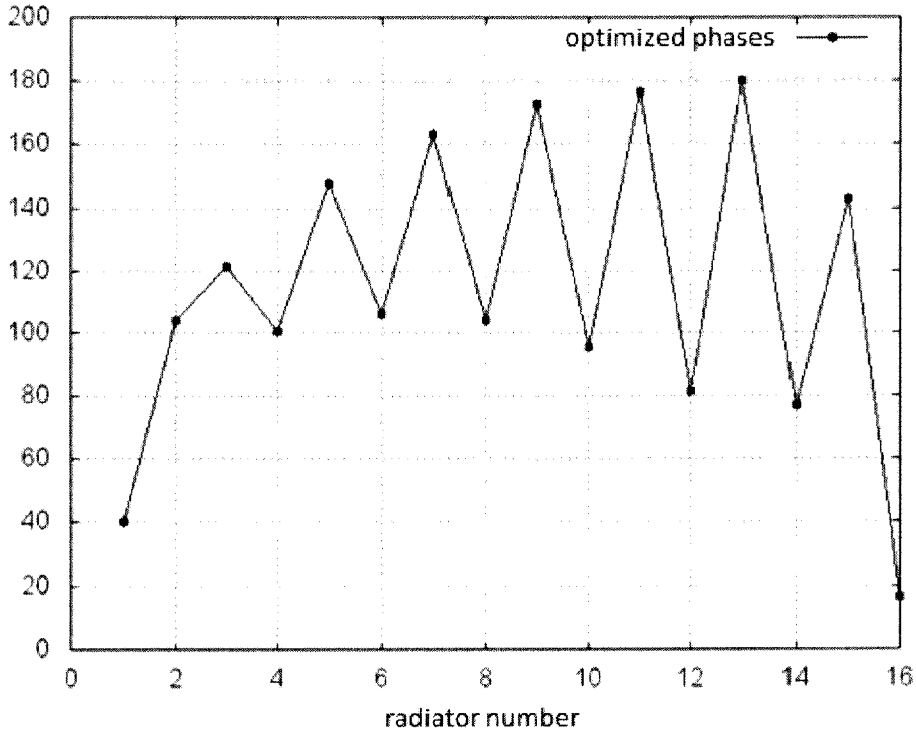

optimized phases
200
180
160
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
radiator number

Fig. 7

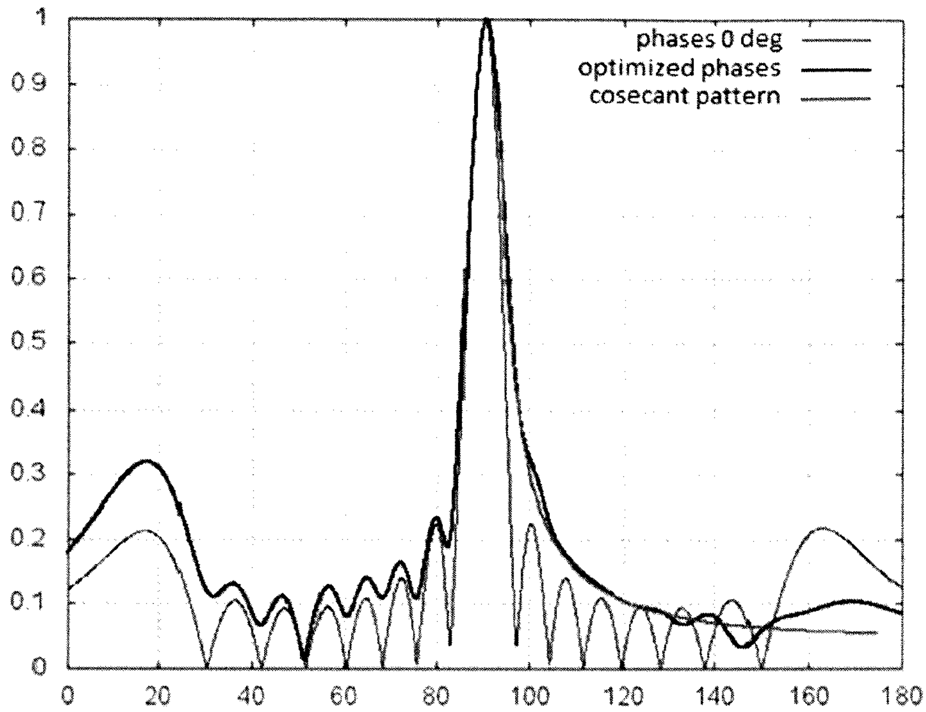

phases 0 deg
optimized phases
cosecant pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
180

Fig. 8

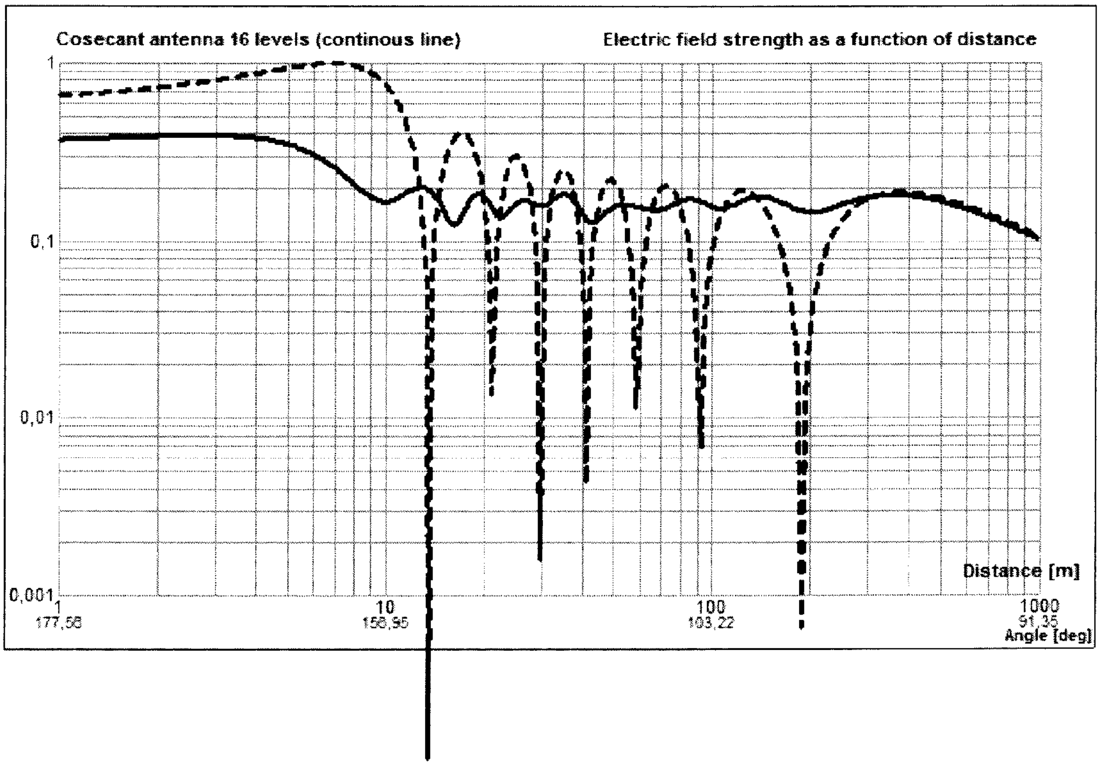

Cosecant antenna 16 levels (continous line)
Electric field strength as a function of distance
1
0,1
0,01
0,001
Distance [m]
1
177,58
10
156,95
100
103,22
1000
91,35
Angle [deg]

Fig. 9

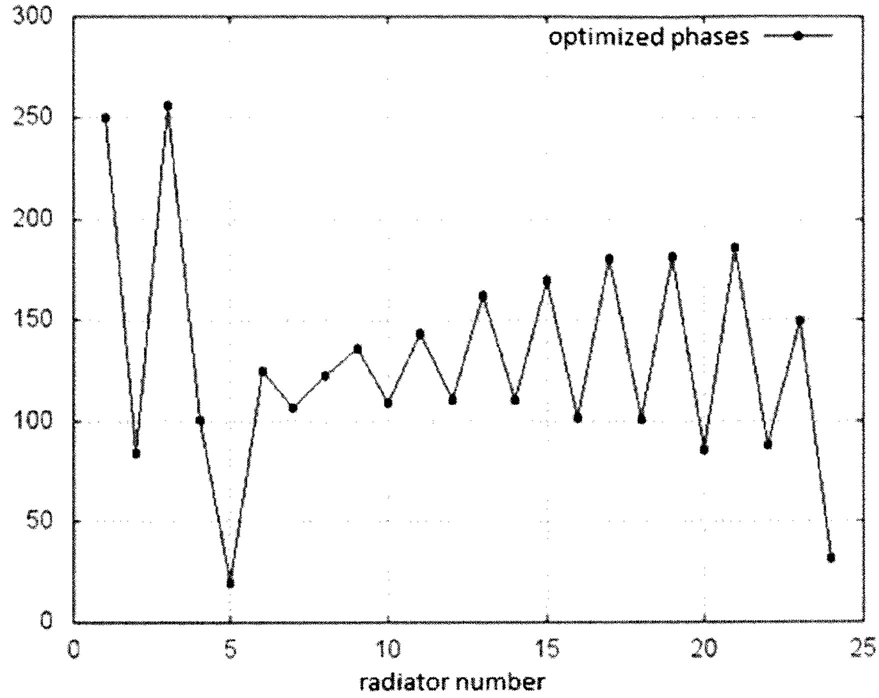

optimized phases
300
250
200
150
100
50
0
0
5
10
15
20
25
radiator number

Fig. 10

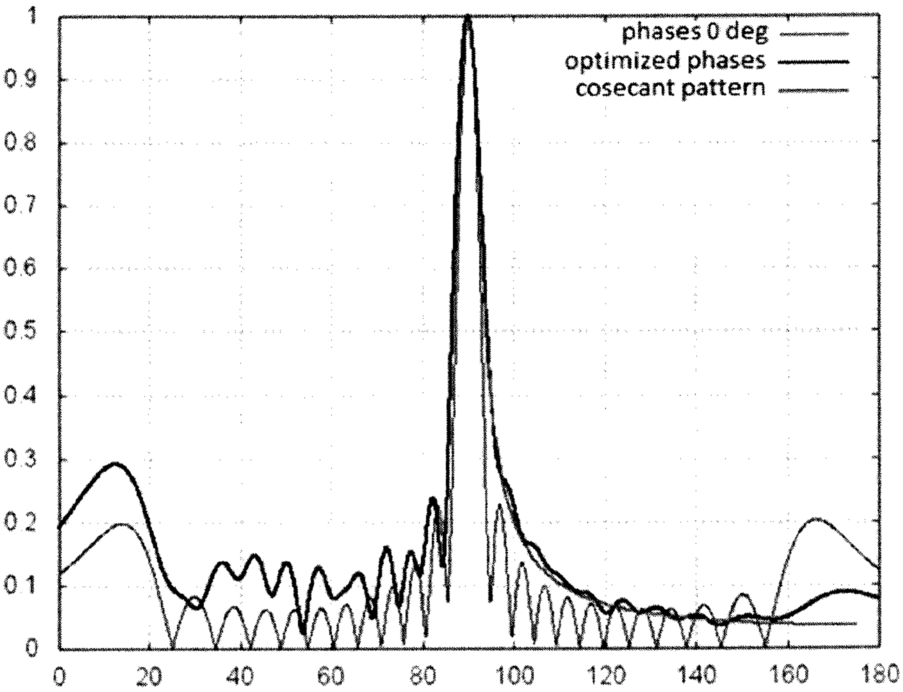

phases 0 deg
optimized phases
cosecant pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
180

Fig. 11

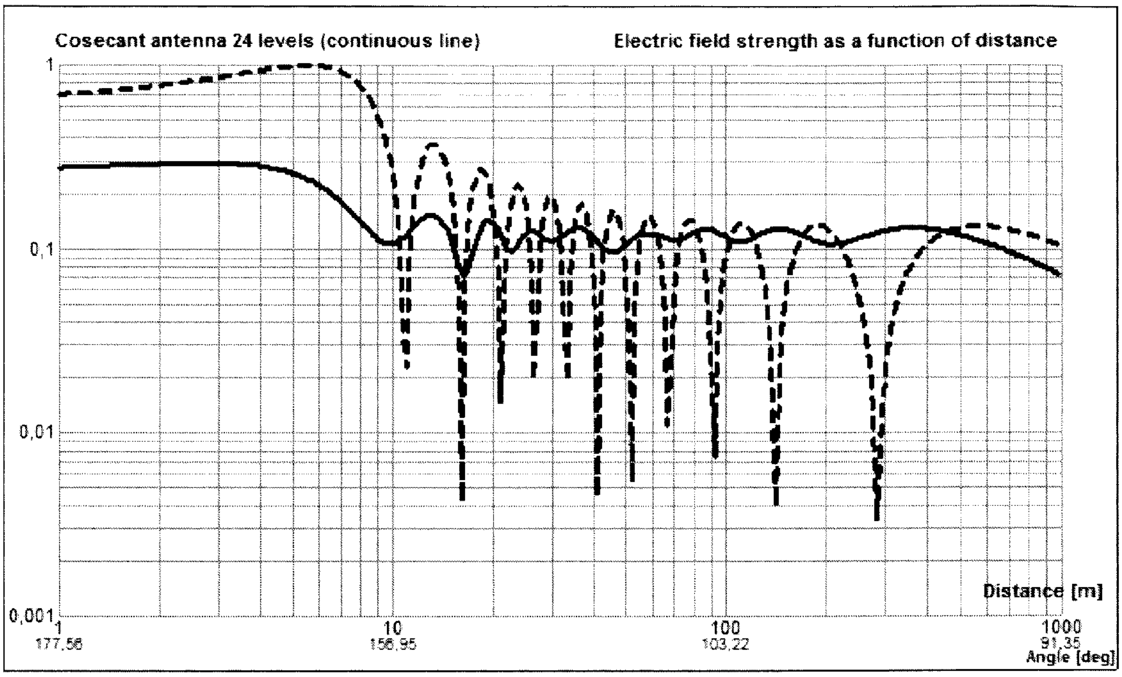

Cosecant antenna 24 levels (continuous line)
Electric field strength as a function of distance
1
0,1
0,01
0,001
1
177,56
10
156,95
100
103,22
1000
91,35
Distance [m]
Angle [deg]

Fig. 12

EUROPEAN SEARCH REPORT

Application Number
EP 15 46 0055

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CHANG MIN-CHI ET AL: "Synthesis of cosecant array factor pattern using particle swarm optimization", 2013 PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ANTENNAS & PROPAGATION, ANTENNA SOCIETY OF THE CHINESE INSTITUTE OF ELECTRONICS, vol. 2, 23 October 2013 (2013-10-23), pages 948-951, XP032554404, ISBN: 978-7-5641-4279-7 [retrieved on 2014-01-20] * Sections I-III; figures 4,5 * -----	1-15	INV. H01Q3/26 H01Q3/30
X	Ananda Kumar Behera ET AL: "Synthesis of Cosecant Squared Pattern in Linear Antenna Arrays using Differential Evolution", 2013 IEEE Conference on Information and Communication Technologies (ICT 2013), 11 April 2013 (2013-04-11), pages 1025-1028, XP055240187, DOI: 10.1109/CICT.2013.6558248 ISBN: 978-1-4673-5758-6 Retrieved from the Internet: URL:http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6558248 [retrieved on 2016-01-11] * Section IV; figure 2 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) H01Q
X	US 2006/007041 A1 (OOMURO NORIHIKO [JP]) 12 January 2006 (2006-01-12)	1-4,6-15	
A	* paragraphs [0049], [0162] - paragraph [0169]; figures 37-40 * -----	5	

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
The Hague	15 January 2016	Sípal, Vít

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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15-01-2016

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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