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(54) **MULTIPLE BAND ANTENNA**

(57) A multiband antenna comprising: at least two sub antennas arranged in a plane and each configured to radiate a respective signal is disclosed. A first of the at least two sub antennas comprises an array of radiating elements, a majority of the radiating elements being arranged at different longitudinal positions within a first longitudinally extending region and a second of the at least two sub antennas comprising an array of radiating elements, a majority of the radiating elements being arranged at different longitudinal positions within a second longitudinally extending region. The first and second longitudinally extending regions are transversely offset with respect to each other and at least one radiating element of the first sub antenna is located within a longitudinally extending region comprising at least one radiating element of the second sub antenna.

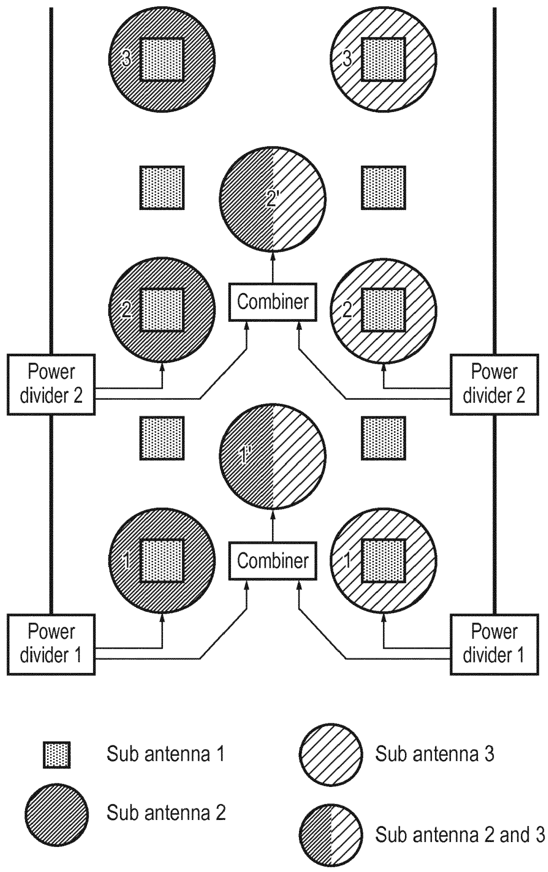

FIG. 4

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Description

FIELD OF THE INVENTION

[0001] The field of the invention relates to multiple band antennas, and in particular to an architecture for such antennas.

BACKGROUND

[0002] A side by side or multiple band base station antenna is one where at least 2 sub-antennas operating in the same frequency band or in close frequency bands, are integrated in the same antenna. There may be more than 2 sub-antennas operating in the same frequency band and/or there may be additional sub-antennas operating in other frequency band(s). Each sub-antenna may be fed with a different signal.

[0003] A challenge with such an arrangement is to maintain the performance of each sub antenna at an acceptable level, while providing an antenna that is compact. This is an increasingly difficult challenge as users look for ever more compact solutions to reduce problems such as visual pollution or wind load.

[0004] Generally, the target 3dB HBW (half power beam width) requested for a sub-antenna is 65° +/-5°. Most of the base station antennas are indeed based on this assumption, and deviating from this value will directly impact the network's performance.

[0005] However, particularly for lower frequency band operations with correspondingly longer wavelengths, it is becoming increasingly difficult to provide such sub antennas with the target 3dB HBW characteristics. Indeed the compactness of the box-kit or housing of such an antenna makes the 65° +/-5° difficult to get, particularly where the box-kit houses 2 sub-antennas operating in the same low frequency bandwidth in a side by side relationship.

[0006] One conventional way of implementing such sub-antennas is shown in figure 1a. In this example the antennas are mounted in the classical side by side arrangement and in order to maintain the 3dB beam width as close as possible to the 65° target, the box kit size and shape is defined accordingly. This principle works satisfactorily for sub-antennas operating at higher frequencies with lower beam widths or with box kits that are not too compact when compared to the operating frequencies.

[0007] A second possible configuration is shown in figure 1b. Here the 2 sub-antennas are interleaved in the longitudinal direction. This limits to some degree the interaction between the 2 sub-antennas. Then if an appropriate box kit shape is selected the 3dB HBW can be maintained close to the required specifications. However, as for the arrangement of Figure 1a when compactness is requested for low frequencies, the 3dB HBW for such an arrangement will exceed the required 65° +/-5°. The box kit defines the outer shape and size of the antenna and relates to the housing in which the antenna is mounted.

[0008] It would be desirable to provide a compact multiband antenna with an acceptable beam width.

SUMMARY

[0009] A first aspect provides a multiband antenna, comprising: at least two sub antennas arranged in a plane and each configured to radiate and/or receive a respective signal; a first of said at least two sub antennas comprising an array of radiating elements, a majority of said radiating elements being arranged at different longitudinal positions within a first longitudinally extending region; a second of said at least two sub antennas comprising an array of radiating elements, a majority of said radiating elements being arranged at different longitudinal positions within a second longitudinally extending region; said first and second longitudinally extending regions being offset with respect to each other in a transverse direction; wherein at least one radiating element of said first sub antenna is located within a longitudinally extending region comprising at least one radiating element of said second sub antenna.

[0010] The inventors of the present invention recognised that the beam width of an antenna will increase as the width of the antenna decreases and that this can become critical for low width antenna operating within lower frequency bandwidths. They also recognised that in a multiband antenna where radiating elements of different sub antenna are often arranged side by side, then in effect each sub antenna only uses a fraction of the total width of the antenna and there is therefore an opportunity to increase the width of at least a portion of the sub antenna and perhaps address the problem of increased beam width. However, radio frequency coupling between the different sub antennas in a multiband antenna should be reduced as much as possible to provide acceptable performance and there is therefore a technical prejudice against moving any of the radiating elements towards each other. The inventors recognised that placing at least one but only a subset of the radiating elements in an axial region that is used to contain at least one radiating element of another sub antenna would provide a reduction in the beam width of that sub antenna and may not increase the coupling between them by too much.

[0011] In some embodiments, the multiband antenna further comprises at least one further longitudinally extending region between said first and second longitudinally extending regions, said at least one further longitudinally extending region comprising at least one radiating element of said first and at least one radiating element of said second sub antenna.

[0012] One way of extending the width of both the first and second sub antenna and thereby reduce their beam widths is to provide an additional longitudinal region between the other regions and place at least one radiating element from each sub antenna in this additional region.

These radiating elements are fed with the same signals as the radiating elements of the sub antenna to which they belong and act to reduce the beam width of the sub antenna and to thereby improve performance. Furthermore, as they are still somewhat removed from the majority of radiating elements of the other sub antenna this arrangement does not decrease performance unduly. However, the use of an additional longitudinal region within which these radiating elements are placed does increase the width of the antenna. This additional longitudinal region between the two longitudinal regions does however provide a gap between most of the radiating elements of the two sub antennas and helps improve the isolation or decoupling between the sub antennas.

[0013] It should be noted that the longitudinal regions should be wide enough to encompass the radiating element. In some embodiments, they are wide enough to encompass staggered radiating elements such that each radiating element is not arranged on a same axis as the other radiating elements but are slightly offset. In some embodiments, the radiating elements may be interleaved so that they are longitudinally offset with respect to each other. In some cases the edge of some of the staggered radiating elements may overlap the edge of the longitudinal region, although their centres will always be within it.

[0014] In some embodiments, said at least one radiating element of said first sub antenna is located in said second longitudinally extending region.

[0015] Alternatively and/or additionally to providing a further longitudinal region the one or more radiating element of the first sub antenna located to widen that sub antenna and reduce the beam width may be placed in the longitudinal region that contains the radiating element of the majority of the radiating elements of the second sub antenna. Where this is an alternative to the additional longitudinal region then the width of the antenna is not increased by this arrangement as a radiating element from one of the sub antennas is simply located in the region housing the radiating elements of the other sub antenna. This is a simple yet effective way of widening the sub antenna and decreasing its beam width without increasing the width of the antenna. Furthermore, the basic architecture of the antenna is not changed with respect to a conventional antenna, it is simply the signal feeding circuitry which needs to be altered making the manufacture and assembly of antennas with different properties convenient and inexpensive.

[0016] In some embodiments, said at least one radiating element of said first sub antenna is located towards one end of said second longitudinally extending region.

[0017] Although the radiating element of the other sub antenna may be located anywhere along the longitudinal direction of the sub antenna, it may be advantageous for it to be located towards one end. As noted previously, coupling between radiating elements of the different sub antennas is to be impeded where possible as this impacts performance. Placing the radiating element of one sub antenna towards the end of the other sub antenna reduces the coupling between the radiating elements and therefore the impact on performance. In this regard, preferably it is the end radiating element such that it is only adjacent to one radiating element from the other sub antenna.

[0018] In some embodiments, at least one radiating element of said second sub antenna is located in said first longitudinally extending region.

[0019] In some cases only one sub antenna is widened by placing a radiating element of that sub antenna in the longitudinal region of the other sub antenna, whereas in other embodiments both sub antenna may be widened by placing radiating elements from each in the longitudinal regions of the other. Again it may be advantageous to place these radiating elements towards the end of the other sub antenna.

[0020] In some embodiments, said at least one radiating element comprises at least one shared radiating element configured to receive signals destined for said at least two sub antennas, such that said at least one shared radiating element comprises a radiating element in each of said two sub antenna arrays.

[0021] An alternative and/or additional way of providing a broadening of the sub antenna is to provide a combined signal to what is in effect a shared radiating element such that in transmission mode this radiating element is fed by a signal for two sub antennas and as such can be considered a radiating element of each. This combining of the signals occurs in the signal feed network and the area where they are combined has a limited impact on the coupling between the signals. Such an arrangement is also efficient in hardware costs. In receiving mode, signals received at this radiating element will be supplied to decoding circuitry of both sub antennas.

[0022] The shared radiating element may be in the longitudinal region of the first or of the second sub antenna and/or it may be in a further intermediate longitudinal region between the regions of the first and second sub antennas.

[0023] In some embodiments, said multiband antenna further comprises a signal feed network configured to supply said respective plurality of signals to radiating elements in said respective plurality of sub antennas; said signal feed network comprising a signal combiner configured to combine at least two signals and to feed said combined signal to said at least one shared radiating element.

[0024] Where there is a shared radiating element then in transmission mode a signal combiner is used to combine the signals for the respective sub antenna that the shared radiating element is to be a part of.

[0025] In some embodiments, said first and second longitudinally extending regions each comprise at least one of said shared radiating element.

[0026] Although only one of the first or second sub antenna may be broadened by using a shared radiating element in the longitudinal region housing the radiating elements of the other sub antenna, in some embodiments both may comprise the shared radiating elements in the offset longitudinal region thereby both having the improved performance of a decreased beam width.

[0027] It may be advantageous in some embodiments for said at least one shared radiating element is located towards one end of said first and second longitudinally extending regions.

[0028] The shared radiating element may increase the coupling between the radiating elements within a sub antenna and it may be advantageous if it is located towards one end of the sub antenna preferably at the end radiating element.

[0029] The first and second sub antennas are configured to operate in similar frequency bands and in some embodiments are configured to operate in the same frequency band. The different signals sent to the two sub antennas may be differently polarised to reduce interference between the signals.

[0030] In some embodiments, said longitudinally extending regions do not overlap and a width of each region is such that a centre of each radiating element within said longitudinally extending regions is less than ¼ of a central wavelength of said frequency band apart.

[0031] The radiating elements are generally arranged in a column type form, one on top of the other. However, there may be some staggering in a transverse direction of these radiating elements depending on the required characteristics of the antenna. However, the staggering is such that at least the centre, and in some cases all of the radiating elements remain within the longitudinally extending regions. The width of these longitudinally extending regions thereby limit the amount of staggering of the radiating elements. The centre of each radiating element within each longitudinally extending region should in any case be less than a quarter of central wave length of said frequency band apart. In other words, radiating elements at each edge of the longitudinally extending regions will always be within a quarter wavelength of each other. Radiating elements which are further apart than this tend to generate lobes in their beams which are not in a desired direction and thereby decrease the performance of the antenna.

[0032] In some embodiments, the multiband antenna further comprises at least one further sub antenna configured to operate in a different higher frequency band to said first and second sub antennas.

[0033] The antenna may also comprise other radiating elements configured to operate in other frequency bands and these may be arranged within the same longitudinally extending regions as the other sub antennas or in other regions.

[0034] The multiband antenna may comprise two or more sub antenna arranged in longitudinally extending regions and configured to operate in a same or similar frequency band.

[0035] Where the antenna has three or more sub antennas each operating in a similar frequency band, the shared radiating element may be shared between all sub antennas and receive signals destined for all of these three or more sub antennas, or it may be shared by a subset of the different sub antennas.

[0036] A second aspect provides a boxkit comprising at least one multiband antenna according to a first aspect, and a radome for housing said at least one multiband antenna.

[0037] A further aspect provides a multiband antenna, comprising: a plurality of sub antennas arranged in a plane and configured to radiate a respective plurality of signals, each of said plurality of sub antennas comprising an array of radiating elements; wherein a plurality of said radiating elements in each sub antenna array are configured to receive a signal destined only for said sub antenna; at least one radiating element comprises a shared radiating element configured to receive signals destined for at least two sub antennas, such that said at least one shared radiating element comprises a radiating element in at least two sub antenna arrays.

[0038] The use of shared radiating elements which receive signals destined for more than one sub antenna allows the sub antennas to in effect overlap and each use a region of the antenna that houses the shared radiating element. This allows the restricted space within the antenna to be efficiently used and can be used to improve the performance of both sub antenna. For example, the width of each sub antenna may be broadened and their beam width correspondingly decreased. Furthermore, in some cases the use of shared radiating element reduces the interference between signals when compared to the use of alternate radiating elements from each antenna owing to the configuration of the signal feed network.

[0039] In some cases the plurality of radiating elements in each sub antenna array configured to receive a signal destined only for said sub antenna are the majority of radiating elements in that sub antenna.

[0040] Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

[0041] Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figures 1a and 1b illustrate conventional multiband antenna architectures;

Figure 2 schematically illustrates an antenna according to an embodiment;

Figure 3 shows an embodiment of an antenna with an additional intermediate region containing radiating elements of each of the first and second sub antenna;

Figure 4 shows an embodiment where there is an intermediate region containing shared radiating elements of the first and second sub antenna;

Figure 5 shows an embodiment where each of the first and second sub antennas contains a shared radiating element;

Figure 6 shows the change in beam width with frequency for a conventional antenna such as that shown in Figure 1a;

Figure 7 shows an antenna configuration similar to that of Figure 3 and the effect this has on the beam width at different frequencies;

Figure 8 shows a configuration of an antenna similar to that shown in Figure 4 along with the beam width to frequency performance; and

Figure 9 shows a configuration of an antenna similar to that of Figure 5 along with the beam width to frequency performance.

DESCRIPTION OF THE EMBODIMENTS

[0043] Before discussing the embodiments in any more detail, first an overview will be provided.

[0044] The housing of more than one sub antenna within one antenna housing provides challenges with performance and compactness. In this regard for the purpose of this patent application a sub antenna is one or more radiating elements fed with the same signal. The sub antenna may operate in the same bandwidth as each other or in different bandwidths. An antenna is one or more sub antenna housed within the same boxkit, radome or housing.

[0045] Radiating elements of each sub antenna operating in the same or similar frequency bands may be arranged substantially in a line that is one on top of each other, with neighbouring sub antennas being located in a side by side arrangement. The width provided for the location of the radiating elements of each sub antenna is restricted by the width of the antenna housing and the location of the other sub antenna. A narrow width of sub antenna that has a low frequency of operation provides a wide beam width which may not be acceptable. This beam width of a sub antenna may be narrowed by locating one or a subset of radiating elements of that sub antenna in line with the radiating elements of another sub antenna.

[0046] Alternatively and/or additionally providing a radiating element that is shared between the sub antennas, that is that receives signals destined for both, can also be used to widen at least a portion of the sub antenna, improve beam width performance and make effective use of the limited space.

[0047] The location of radiating elements of different sub antennas affects the performance of the sub antennas and as such changing the radiating elements location can be used to change the performance of the sub antenna. It should be noted that a radiating element is deemed to be within a certain sub antenna if it is fed with a signal destined for that sub antenna. Thus, a location of a radiating element can be changed simply by changing the signal feed network, so that a radiating element that is aligned with radiating elements of one sub antenna, if fed with a shared signal or with a signal for another sub antenna, then becomes an element for that sub antenna and the performance of the antenna is changed without the architecture of the radiating elements being altered.

[0048] As the beam width of a sub antenna is affected by the width of the sub antenna, then providing a radiating element in a different transverse position to other radiating elements within the antenna will affect the beam width. As multiband antenna are generally arranged with sub antenna arranged substantially along different parallel longitudinal axes, albeit the radiating elements may not be in an exact column but may be slightly staggered, placing a radiating element of one sub antenna in a region housing radiating elements of another sub antenna can affect the beam width without increasing the overall width of the antenna.

[0049] It should be noted that a longitudinal region is deemed to be substantially parallel with another longitudinal region if the different in distance between adjacent edges of the regions varies by less than 10% from one end to the other.

[0050] Figure 2 schematically illustrates one embodiment, where the effect of placing a radiating element of sub antenna 1 in the longitudinal region containing the radiating elements of another sub antenna 2 is shown. In this regard signal 1 is sent to sub antenna 1 and signal 2 to sub antenna 2. Radiating elements 10 are radiating elements of sub antenna 1, while radiating elements 20 are radiating elements of sub antenna 2. Radiating element 12 is a shared radiating element that receives both signal 1 and signal 2 via a signal combiner and is therefore a radiating element of both sub antenna 1 and sub antenna 2. In this context one can see that the beam width of 75° of the upper two radiating elements 10 is changed to a beam width of 45° for the adjacent lower radiating elements 10, 12, giving an overall beam width within acceptable limits for the sub antenna. Thus, the use of a signal divider to split the signal and feed a radiating element located in the array of the other sub antenna provides a decrease in beam width. Thus, this is an effective solution for providing multiband antenna of a compact size which meets the 65° HBW.

[0051] Figure 3 shows an antenna according to a further embodiment with an additional intermediate longitudinal region between the two longitudinal regions that house the sub antenna 2 and sub antenna 3 which are sub antenna operating in a same frequency band. In this embodiment one radiating element from each of these two sub antennas is placed in this additional intermediate longitudinal region and in this way the physical width of each of these sub antennas is increased and thereby their beam widths are decreased. A power divider is used to divide the signal sent to the radiating elements in the column of elements forming the main part of the sub antenna arrays such that the signal is split and a portion of the signal is sent to the radiating elements in the intermediate region.

[0052] It should be noted that in this embodiment the antenna comprises a further sub antenna, sub antenna 1 that operates at a different frequency band to the band of operation of sub antenna 2 and 3. Sub antenna 1 is arranged in both the two outer longitudinal regions. It can be located to use the whole width of the antenna as it is the only sub antenna operating in this frequency band and as such does not need to share the width of the antenna with another sub antenna. In some cases the radiating elements of this sub antenna 1 are shown as being located at the same longitudinal position as radiating elements of the second and third sub antenna. It should be noted that these radiating elements are arranged in different planes such that they are stacked one behind the other.

[0053] Although, in the example shown there is only one radiating element from each sub antenna 2 and 3 in the central longitudinal region, in other embodiments there may be several of these radiating elements and in such a case these may be arranged in an alternate fashion. It should also be noted that in order to reduce the impact due to coupling between radiating elements of different sub antenna they may preferably be arranged at different longitudinal positions such that they are interleaved.

[0054] Another example which operates on similar principles is depicted in Figure 4. The arrangement of Figure 3 may cause some interference problems between the two sub antennas either in the H or the V plane of the beams because of the alternate feeding of the radiating elements. In order to address this problem an alternative is proposed where the radiating elements in the central region belong to both sub antennas. For this to occur a combiner is used which combines the signals making these radiating elements shared radiating elements which are fed by signals from both sub antenna. Not only does this reduce interference but this is an effective use of both space and hardware.

[0055] Figure 5 shows an alternative embodiment where compactness is improved. In the embodiments of Figure 3 and 4 an additional longitudinal region is provided for the offset radiating elements used to increase the physical width of the different sub antenna. This increases the overall width of the antenna. In the embodiment of Figure 5, there is no additional intermediate longitudinal region and as such a more compact antenna can be provided. In this case, a combiner is again used to combine signals for each of the sub antennas and a radiating element towards each end of each sub antenna is fed with the combined signals such that it becomes a shared radiating element for the two sub antennas. These shared radiating elements are arranged at or towards one end of the antenna and again the radiating elements of sub antenna 2 and 3 which operate in the same frequency band are longitudinally offset with respect to each other to reduce interference. Again this embodiment comprises an additional sub antenna, sub antenna 1 which operates at a different higher frequency band and comprises a number of radiating elements located across the physical width of the antenna.

[0056] Figures 6 to 9 show how the different embodiments affect the performance of the antennas. The examples given concern a ±45° polarized dual band antenna, having a requested 65° +/-5° 3dB HBW over the bandwidth (698MHz-960MHz). In order to limit visual impact the width of the box kit is chosen to be 1λ, which is quite challenging to ensure the 3dB HBW requested.

[0057] Figures 6 shows -3dB half power beam width of the radiated field in the H-plane over the bandwidth of a conventional antenna such as that shown in Figure 1a where two adjacent columns of radiating elements form the two sub antennas. As can be seen the beam width of the two sub antenna becomes wider than is generally accepted at lower frequencies. The 3dB HBW varies from 95° @690MHz to 68°@960MHz. In this configuration each column is fed sparsely.

[0058] Figure 7 shows how having an intermediate region with radiating element from each sub antenna arranged alternately can affect the beam width. The result is clearly improved, as the 3dB HBW varies now from 78° to 58° and may reach acceptable levels at about 0.8 GHz.

[0059] Figure 8 shows an alternative embodiment where the intermediate region comprises shared radiating elements fed by a signal combiner so that the two radiating elements in the intermediate region act for both sub antennas and this provides an improved effect. In this configuration the 3dB HBW varies from 70° to 50°. As 50° is too narrow, an alternative could be to use the antenna in the normal way for frequencies from 840MHz to 960MHz and to use a third column with a radiating element operating from 690MHz to 840MHz. Using this configuration, 3dB HBW can vary from 70° to 60°.

[0060] Figure 9 presents a more "compact" configuration. Here the geometry of the box kit has been reduced from 1λ to 0.85λ. In this configuration, a third column is not possible as the radiating elements will be too close. In this example the 3dB HBW varies from 65° to 48°. In order to meet the 65° +/-5° the use of the second element need be provided for only one part of the frequency band.

[0061] The presence of the radiating element within a particular sub antenna is defined by the feed network and as such control of whether the transversely offset radiating element is used within a sub antenna can be selected by controlling the signal feed network, in this embodiment by controlling the combiner. Thus, depending on the frequency of operation and on whether the use of an offset radiating element is required for the beam width, this radiating element can be fed with a signal for the sub antenna or not.

[0062] Thus as can be seen offsetting radiating elements with respect to the usual longitudinal region in which the sub antenna are located can provide a decreased beam width. Using shared radiating elements to provide such an offset direction is a particularly effective way of improving performance and also reduces hardware costs and can lower interference.

[0063] In summary, the objective of building an antenna array in the H-Plane in order to provide an acceptable 3dB HBW is achieved by increasing the physical width of the sub antennas for a portion of the length of the sub antenna. To achieve this, in one embodiment a third column between the 2 "normal" sub-antennas is introduced and central radiating elements placed within it, which belong alternately to the first and to the second sub antenna. To feed these radiating elements, the output of the signal feed network is split using a power divider to feed each radiating element (figure 3). In addition, the radiating elements in this third column may be interleaved with the two other columns of radiating elements to minimize or at least reduce the impact.

[0064] Another embodiment following the same principle is depicted in figure 4. A potential problem with the above example arises because of the alternate feeding of the radiating elements. This may cause problems either in the H-plane or in the V-plane. For this reason, an alternative is proposed, where a third column is provided, but where the radiating elements belong to the 2 sub-antennas. For that a combiner is used (see figure 4).

[0065] A third embodiment is given that mixes the two earlier embodiments. This embodiment seeks to provide increased compactness and as such does not use a third column. For this reason, in figure 5 another geometry is provided that follows the same basic idea of creating an array in the H-plane. In this example, the 2 columns are interleaved, and the second sub-antenna will replace the third element for the first sub-antenna, and then in the same way, the first sub-antenna will replace the third element for the second antenna. A combiner is also used to combine both signals.

[0066] The radiating element is depicted as a dipole but it is clear to the skilled person that other elements can be used such as, but not limited to, a patch.

[0067] The multiband antenna arrangement may be configured to operate in a plurality of operational frequency bands. For example, the operational frequency bands may include (but are not limited to) operational frequency bands of 3GPP standards (4G) and any predecessor systems like 1G/2G/3G (including intermediate systems, for example 2.5G) and future systems like 5G. Specifically they may include Long Term Evolution (LTE) (US) (734 to 746 MHz and 869 to 894 MHz), Long Term Evolution (LTE) (rest of the world) (791 to 821 MHz and 925 to 960 MHz); wireless local area network (WLAN) (2400-2483.5 MHz); hiper local area network (HiperLAN) (5150-5850 MHz); US - Global system for mobile communications (US-GSM) 850 (824-894 MHz) and 1900 (1850 - 1990 MHz); European global system for mobile communications (EGSM) 900 (880-960 MHz) and 1800 (1710 - 1880 MHz); European wideband code division multiple access (EU-WCDMA) 900 (880-960 MHz); personal communications network (PCN/DCS) 1800 (1710-1880 MHz); US wideband code division multiple access (US-WCDMA) 1700 (transmit: 1710 to 1755 MHz, receive: 2110 to 2155 MHz) and 1900 (1850-1990 MHz); wideband code division multiple access (WCDMA) 2100 (transmit: 1920-1980 MHz, receive: 2110-2180 MHz); personal communications service (PCS) 1900 (1850-1990 MHz); time division synchronous code division multiple access (TD-SCDMA) (1900 MHz to 1920 MHz, 2010 MHz to 2025 MHz), ultra wideband (UWB) Lower (3100-4900 MHz); UWB Upper (6000-10600 MHz); worldwide interoperability for microwave access (WiMAXs) (2300-2400 MHz, 2305-2360 MHz, 2496-2690 MHz, 3300-3400 MHz, 3400-3800 MHz, 5250-5875 MHz

[0068] For the sake of this patent application radiating elements should be considered to be substantially in line and along an axis if the centers of each radiating element deviate from the axis by less than 1/8 of a central wavelength of the frequency band that they are configured to radiate in. Axes and regions are deemed to be substantially parallel if a distance between the top and bottom of the two axes differs by less than 10%.

[0069] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

[0070] The functions of the various elements shown in the Figures, including any functional blocks labelled as "processors" or "logic", may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" or "logic" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the Figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0071] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0072] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. A multiband antenna comprising:

> at least two sub antennas arranged in a plane and each configured to radiate and/or receive a respective signal;
> a first of said at least two sub antennas comprising an array of radiating elements, a majority of said radiating elements being arranged at different longitudinal positions within a first longitudinally extending region;
> a second of said at least two sub antennas comprising an array of radiating elements, a majority of said radiating elements being arranged at different longitudinal positions within a second longitudinally extending region;
> said first and second longitudinally extending regions being transversely offset with respect to each other; wherein
> at least one radiating element of said first sub antenna is located within a longitudinally extending region comprising at least one radiating element of said second sub antenna.

2. A multiband antenna according to claim 1, further comprising at least one further longitudinally extending region between said first and second longitudinally extending regions, said at least one further longitudinally extending region comprising at least one radiating element of said first and at least one radiating element of said second sub antenna.

3. A multiband antenna according to any preceding claim, wherein said at least one radiating element of said first sub antenna is located in said second longitudinally extending region.

4. A multiband antenna according to claim 3, wherein said at least one radiating element of said first sub antenna is located towards one end of said second longitudinally extending region.

5. A multiband antenna according to claim 3 or 4, wherein at least one radiating element of said second sub antenna is located in said first longitudinally extending region.

6. A multiband antenna according to claim 5, wherein said at least one radiating element of said second sub antenna is located towards one end of said first longitudinally extending region.

7. A multiband antenna according to any preceding claim, wherein:

> at least one radiating element comprises at least one shared radiating element configured to receive signals destined for said at least two sub antennas, such that said at least one shared radiating element comprises a radiating element in said two sub antenna arrays.

8. A multiband antenna according to claim 7, said multiband antenna further comprising:

> a signal feed network configured to supply said respective plurality of signals to radiating element in said respective plurality of sub antennas;
> said signal feed network comprising a signal combiner configured to combine at least two signals and to feed said combined signal to said at least one shared radiating element.

9. A multiband antenna according to claim 7 or 8, wherein said at least one radiating element of said first sub antenna located in a longitudinally extending region comprising at least one radiating element of said second sub antenna comprises said shared radiating element.

10. A multiband antenna according to any one of claims 7 to 9 when dependent on claim 2, wherein said at least one shared radiating element is located in said at least one further longitudinally extending region.

11. A multiband antenna according to any one of claims 7 to 9, wherein
said first and second longitudinally extending regions each comprise at least one of said shared radiating element.

12. A multiband antenna according to claim 11, wherein said at least one shared radiating element is located towards one end of said first and second longitudinally extending regions.

13. A multiband antenna according to any preceding claim, where said first and second sub antennas are configured to operate in a same frequency band.

14. A multiband antenna according to claim 13, wherein said longitudinally extending regions do not overlap and a width of each region is such that a centre of each radiating element within said longitudinally extending regions is less than ¼ of a central wavelength of said frequency band apart.

15. A boxkit comprising at least one multiband antenna according to any preceding claim, and a radome for housing said at least one multiband antenna.

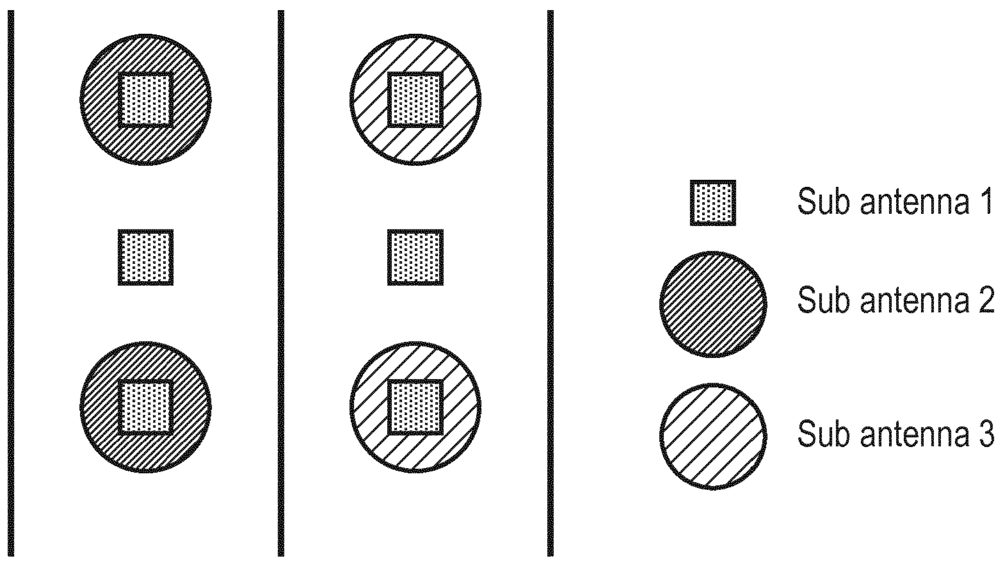

Sub antenna 1
Sub antenna 2
Sub antenna 3

FIG. 1A

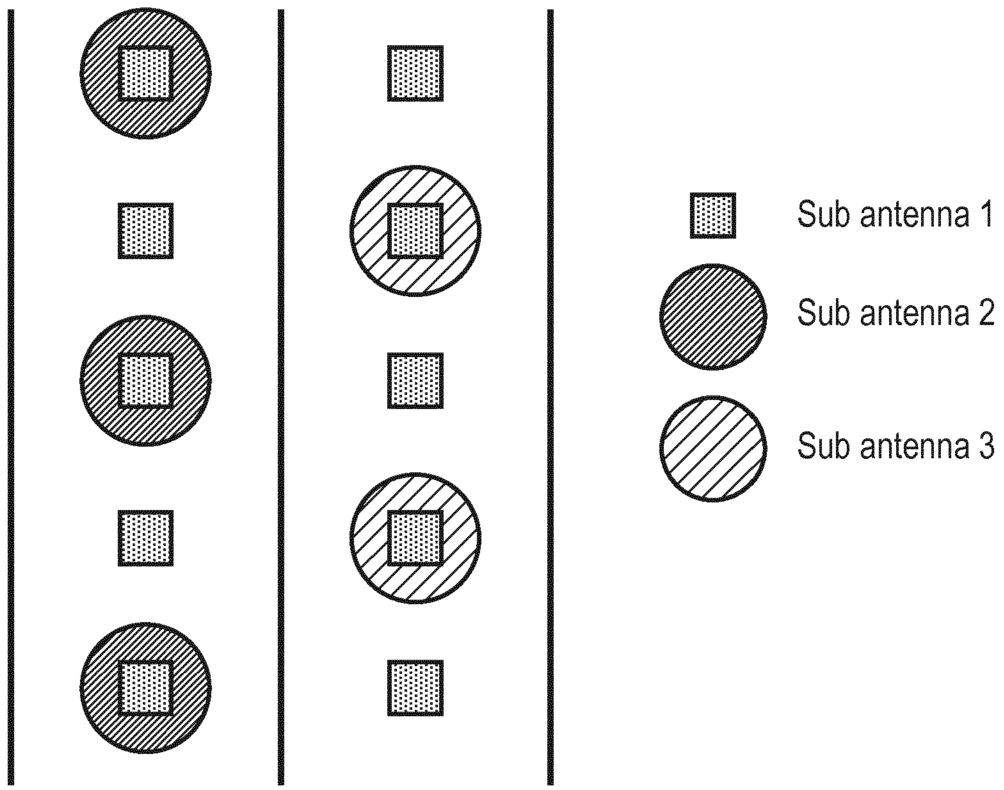

Sub antenna 1
Sub antenna 2
Sub antenna 3

FIG. 1B

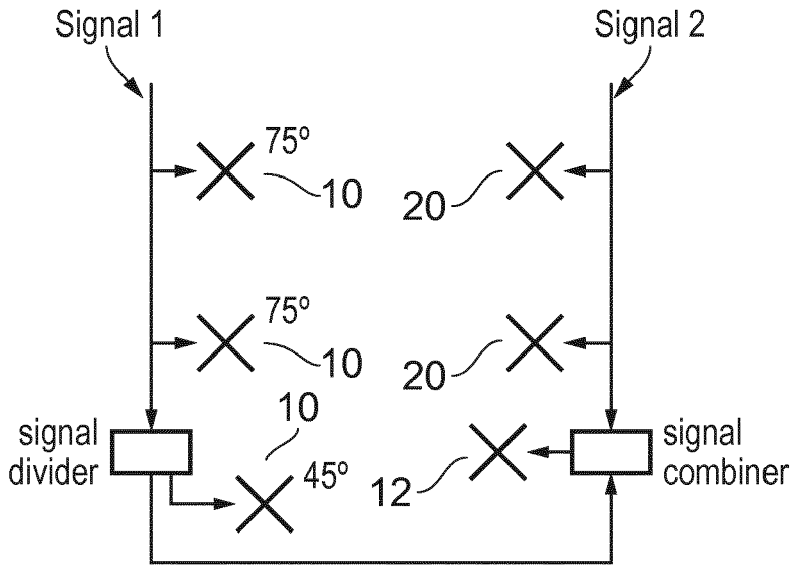

Signal 1
Signal 2
75°
10
20
75°
10
20
10
signal divider
45°
12
signal combiner

FIG. 2

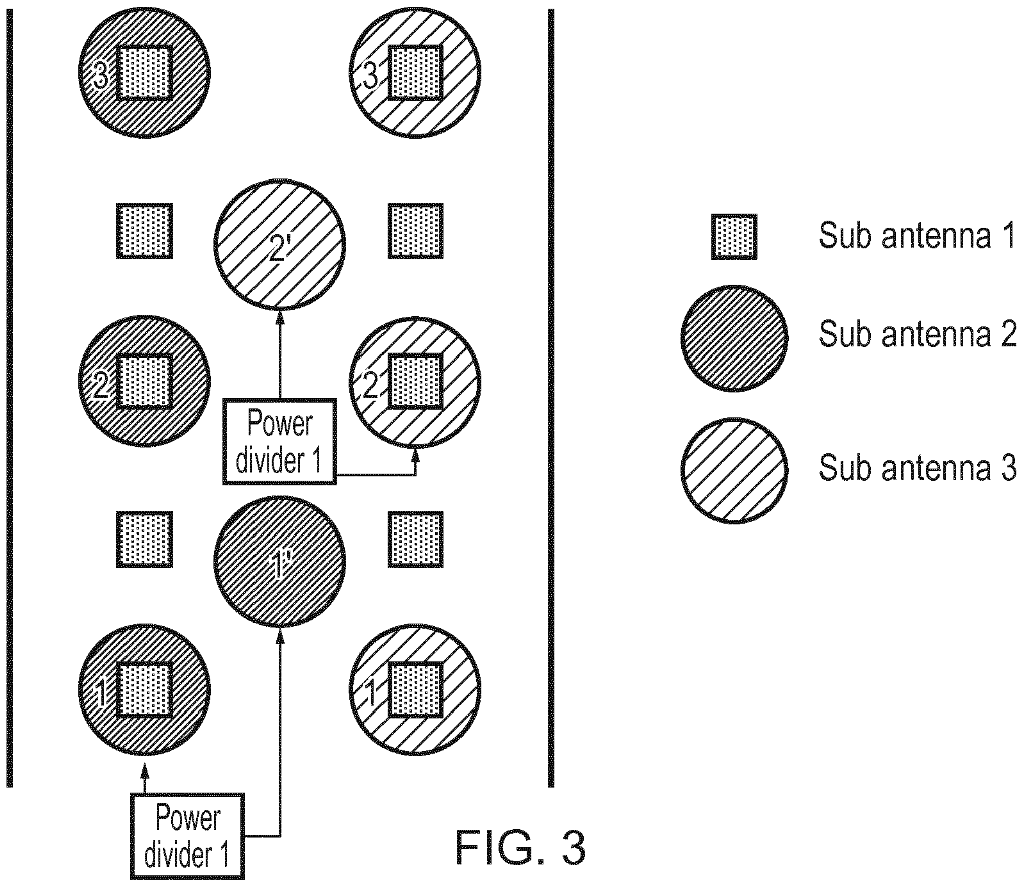

3
3'
2'
2
2'
Power divider 1
1'
1
1'
Power divider 1
Sub antenna 1
Sub antenna 2
Sub antenna 3

FIG. 3

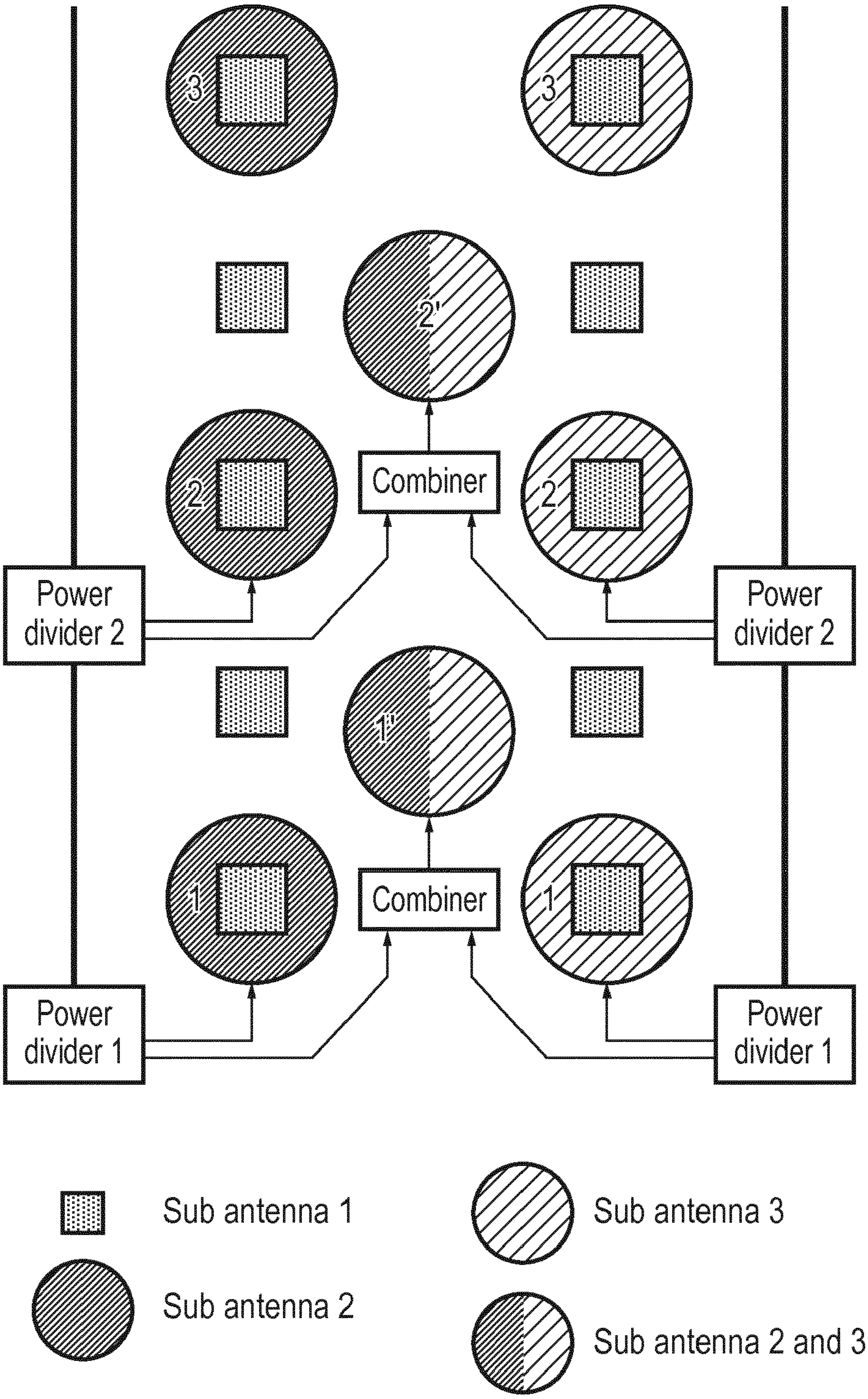

3
3
2'
2
Combiner
2
Power divider 2
Power divider 2
1'
1
Combiner
1
Power divider 1
Power divider 1
Sub antenna 1
Sub antenna 2
Sub antenna 3
Sub antenna 2 and 3

FIG. 4

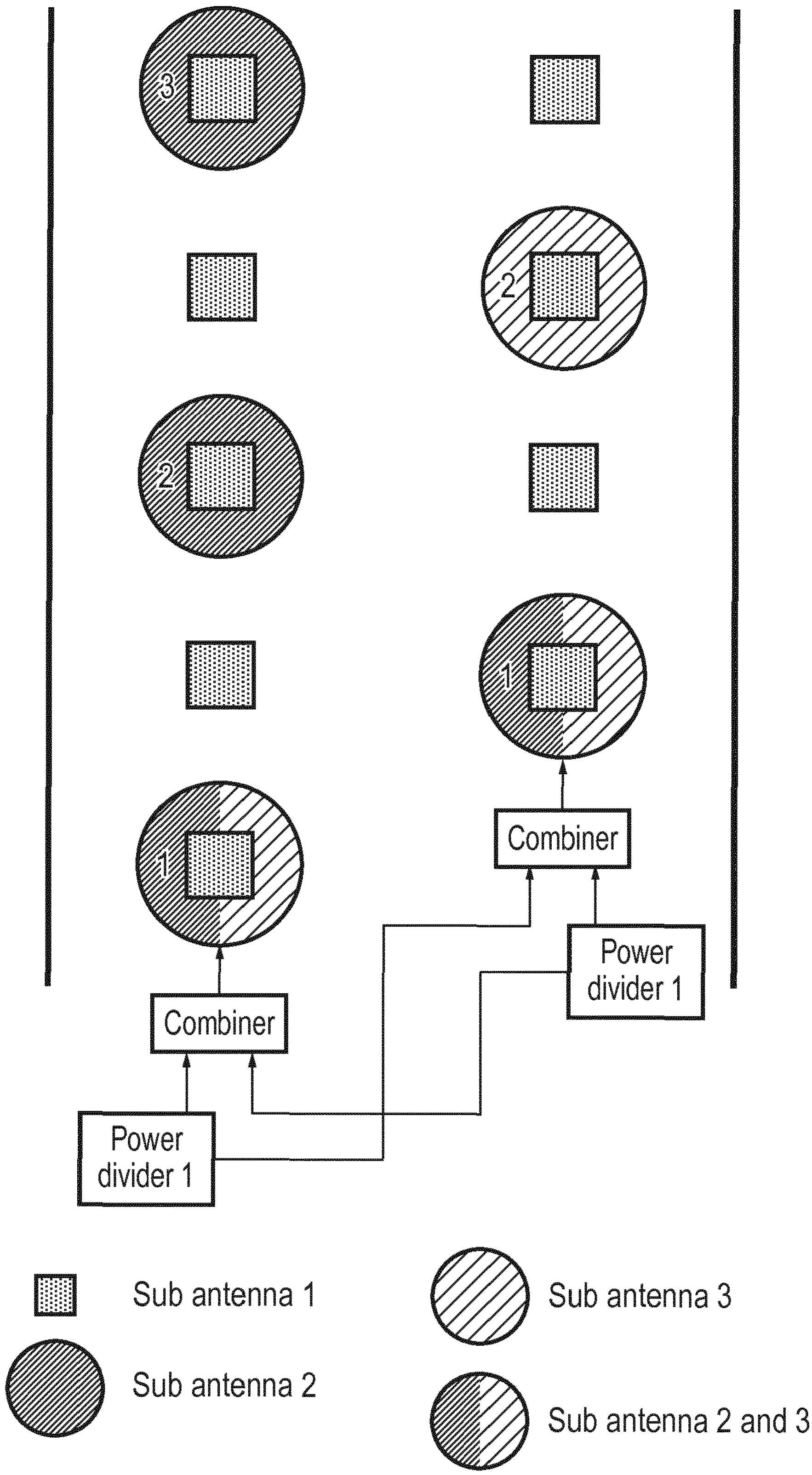

3
2
2
1
1
Combiner
Combiner
Power
divider 1
Power
divider 1
Sub antenna 1
Sub antenna 2
Sub antenna 3
Sub antenna 2 and 3

FIG. 5

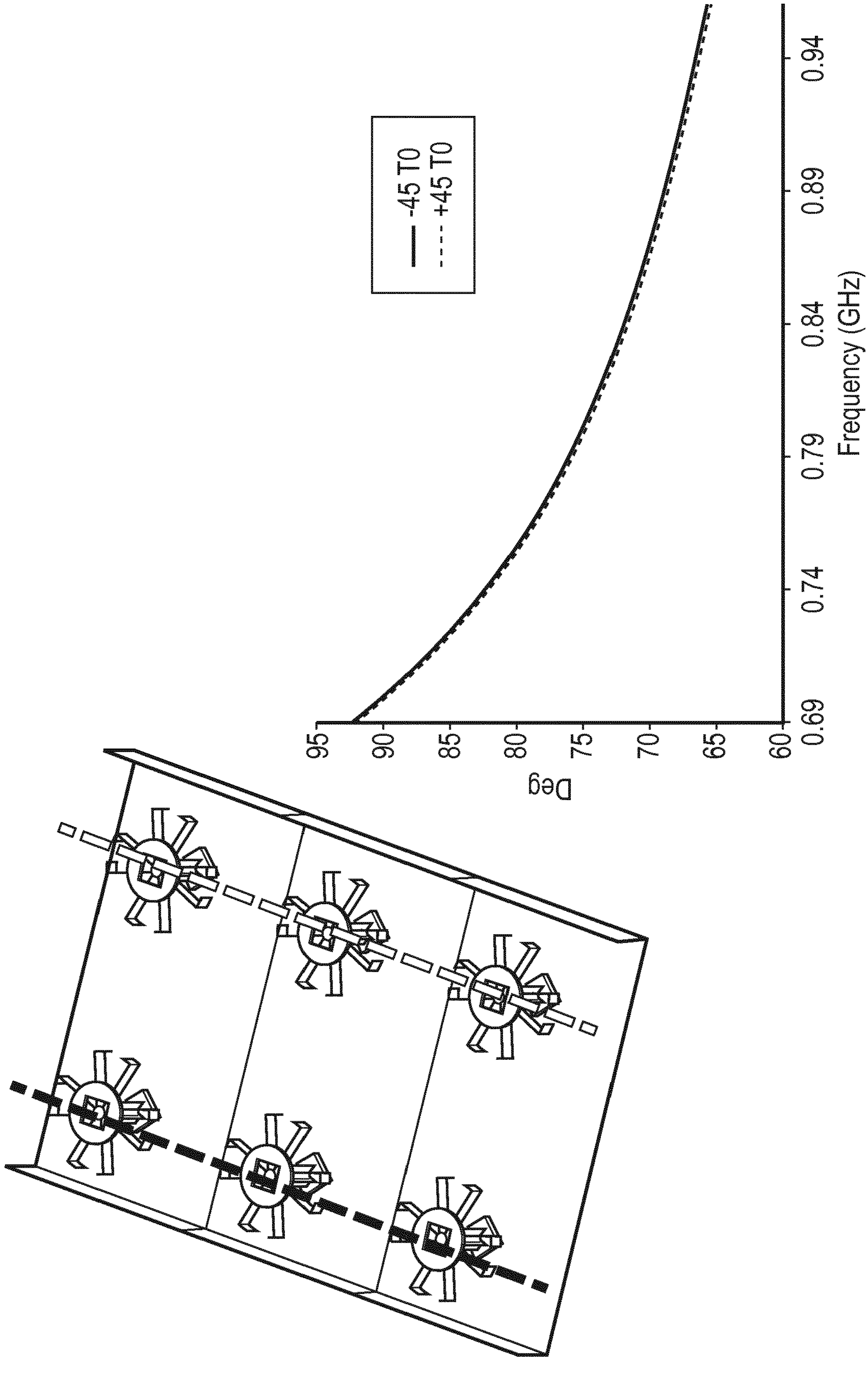
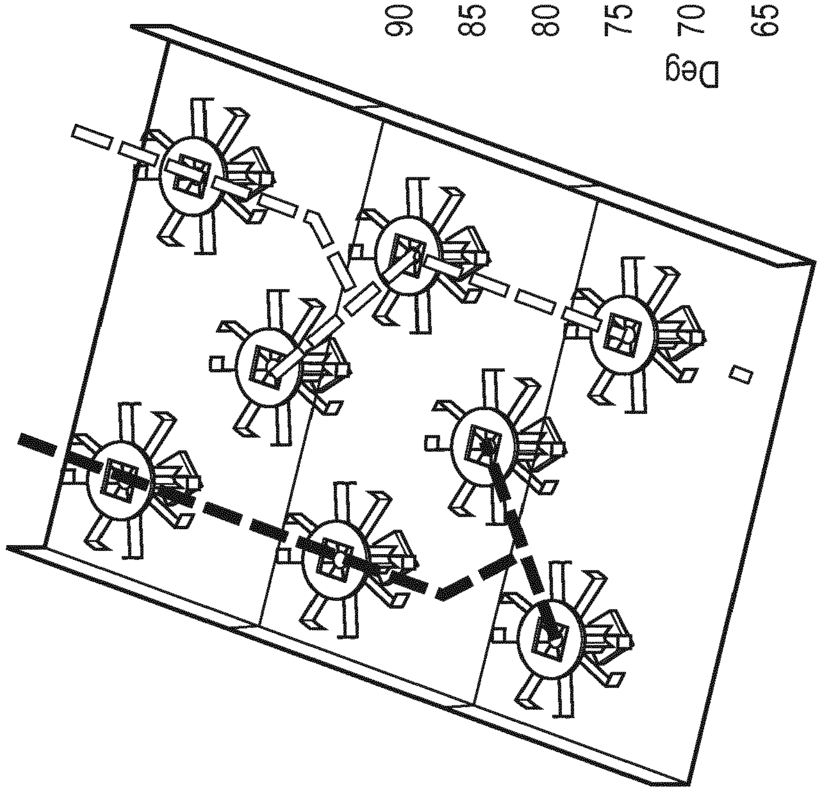

-45 T0
+45 T0
Deg
95
90
85
80
75
70
65
60
0.69
0.74
0.79
0.84
0.89
0.94
Frequency (GHz)

FIG. 6



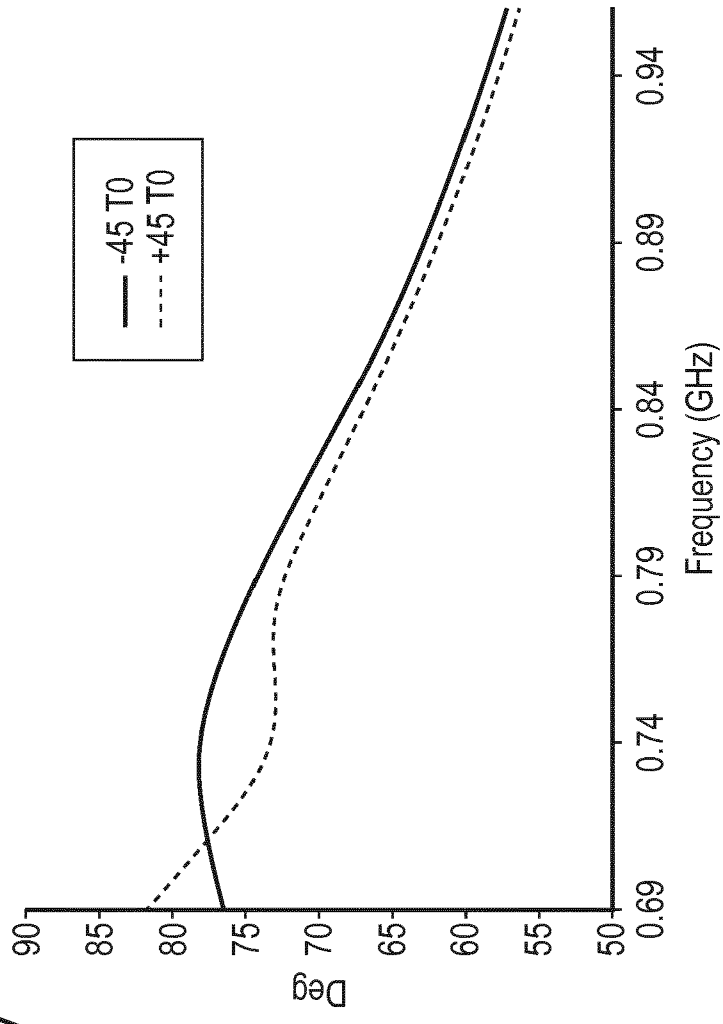

-45 T0
+45 T0
Deg
90
85
80
75
70
65
60
55
50
0.69
0.74
0.79
0.84
0.89
0.94
Frequency (GHz)

FIG. 7

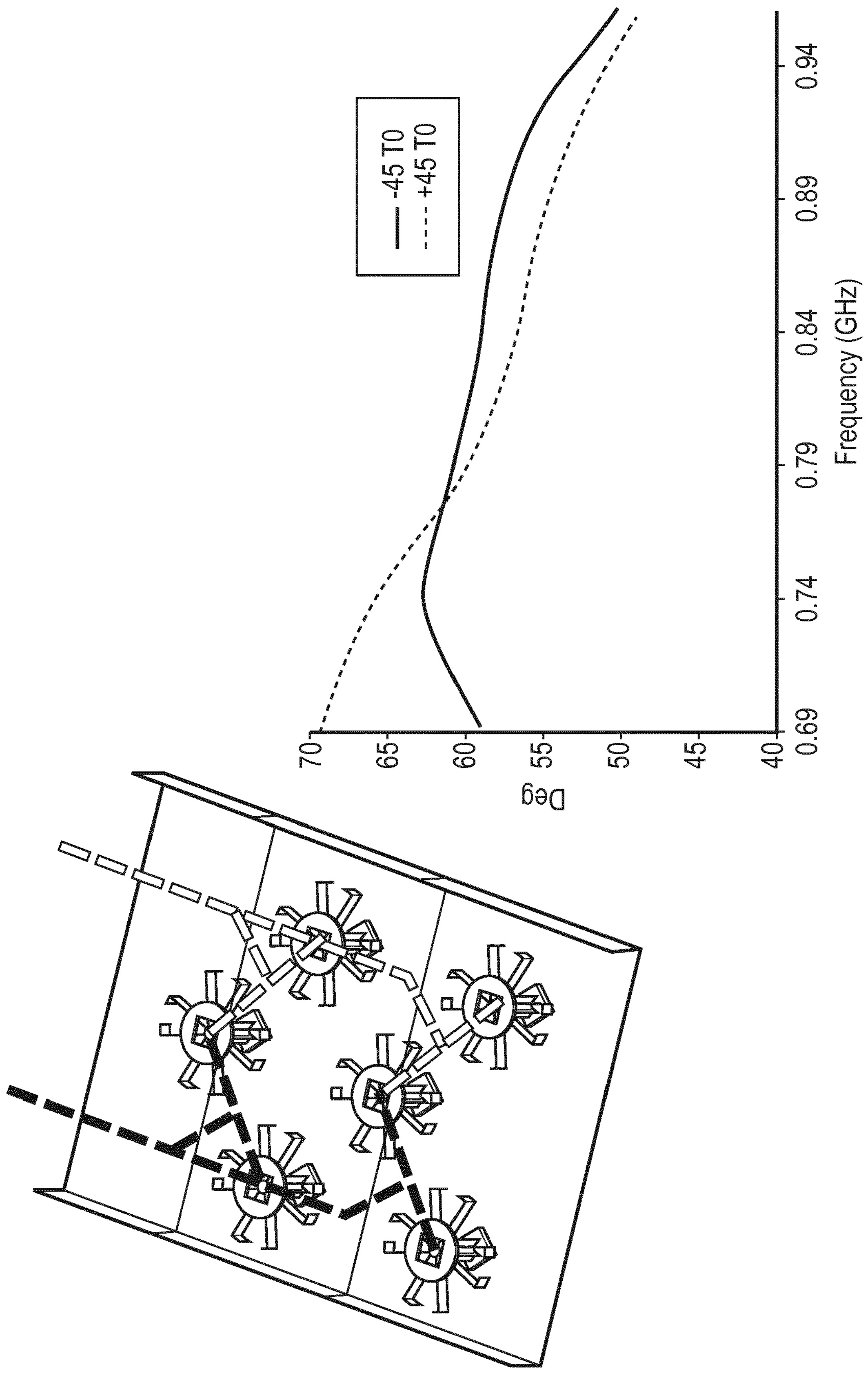

-45 T0
+45 T0
Deg
70
65
60
55
50
45
40
0.69
0.74
0.79
0.84
0.89
0.94
Frequency (GHz)

FIG. 8

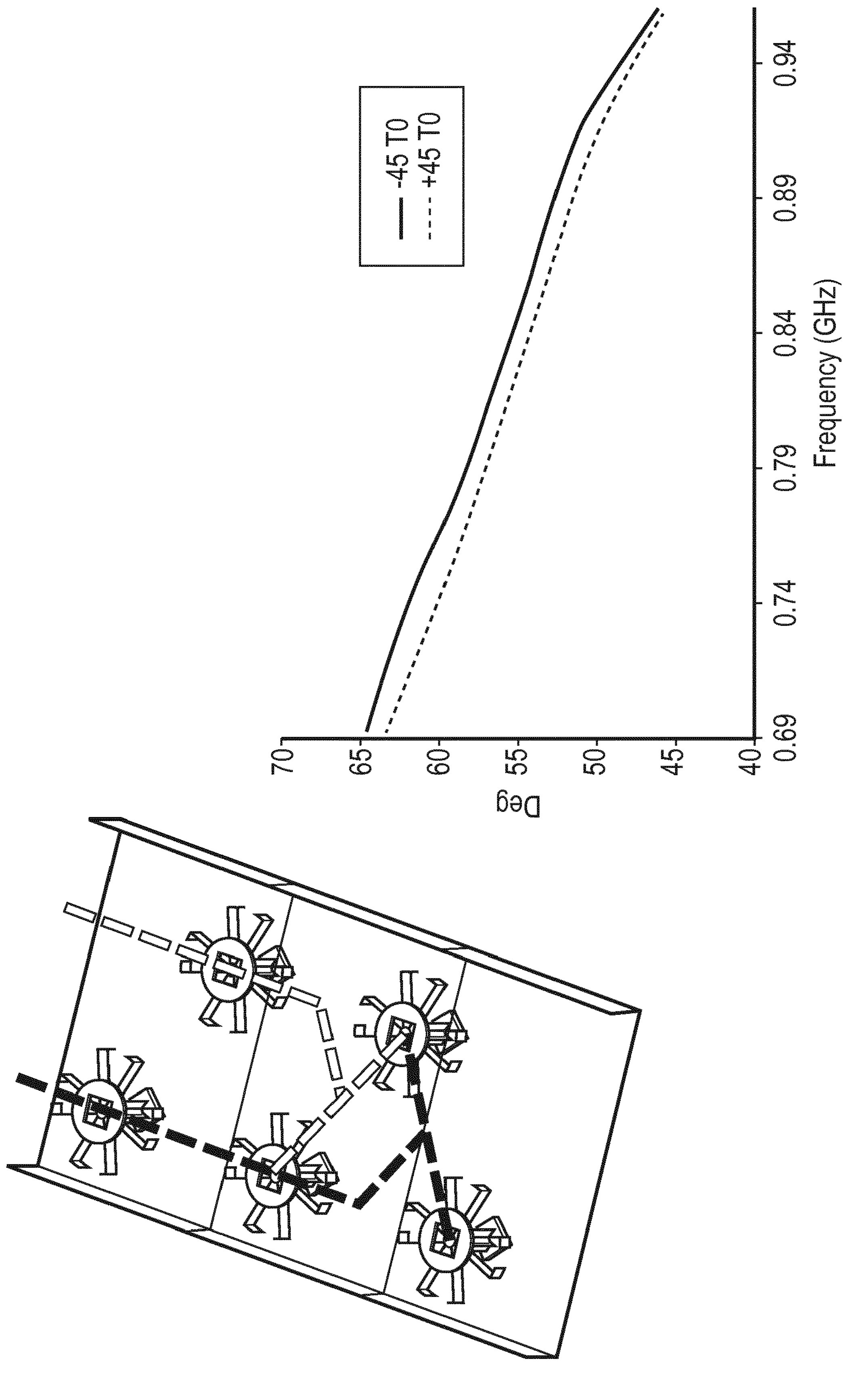

-45 T0
+45 T0
70
65
60
55
50
45
40
Deg
0.69
0.74
0.79
0.84
0.89
0.94
Frequency (GHz)

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 17 19 2469

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 A	US 2004/108956 A1 (GOTTL MAX [DE] ET AL) 10 June 2004 (2004-06-10) * paragraph [0037] - paragraph [0067]; figures 1,4 *	1,3-6, 13-15 2,7-12	INV. H01Q1/24 H01Q21/00 H01Q21/06 H01Q21/28 H01Q21/29
X A	US 2014/225792 A1 (LEE SEUNG-CHEOL [KR] ET AL) 14 August 2014 (2014-08-14) * paragraph [0049] - paragraph [0055]; figure 3 *	1-12,15 13,14	
X A	US 2011/148730 A1 (GOTTL MAXIMILIAN [DE]) 23 June 2011 (2011-06-23) * paragraph [0071]; figure 9 *	1,2, 7-10, 13-15 3-6,11, 12	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 March 2018	Sípal, Vít

CATEGORY OF CITED DOCUMENTS

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14-03-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004108956 A1	10-06-2004	CN 2658958 Y	24-11-2004
		DE 10256960 B3	29-07-2004
		TW 200410447 A	16-06-2004
		US 2004108956 A1	10-06-2004
US 2014225792 A1	14-08-2014	JP 5940570 B2	29-06-2016
		JP 2014155226 A	25-08-2014
		KR 20140101179 A	19-08-2014
		US 2014225792 A1	14-08-2014
US 2011148730 A1	23-06-2011	NONE	

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