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(54) **MULTIPLE FEEDS PER BEAM ANTENNA ARRAY FEED SYSTEM USING A QUASI-PERIODIC MULTI-PORT COUPLER**

(57) The invention provides a multiple feeds per beam antenna array feed system using a quasi-periodic multi-port coupler. The multiple feeds per beam antenna array feed system comprises a quasi-periodic multi-port coupler and an antenna array. The quasi-periodic multi-port coupler is adapted and arranged to distribute power from an input port of at least two input ports to the output port corresponding to the input port and to two output ports adjacent to the output port corresponding to the input port. The antenna array is connected to the quasi-periodic multi-port coupler. The antenna array is further adapted and arranged to be fed by or to feed the quasi-periodic multi-port coupler. The antenna array is

further adapted and arranged to transmit or receive at least two beams. The antenna array comprises a plurality of antennas. Each antenna of the plurality of antennas is adapted and arranged to transmit or receive an electromagnetic wave having a same polarization. A combination of electromagnetic waves transmitted or received by a subset of the plurality of antennas forms one of the at least two beams. Exactly one antenna, for example per quasi-periodic multi-port coupler, of the subset is used as a common antenna with respect to two beams of the at least two beams to be transmitted or received by the antenna array.

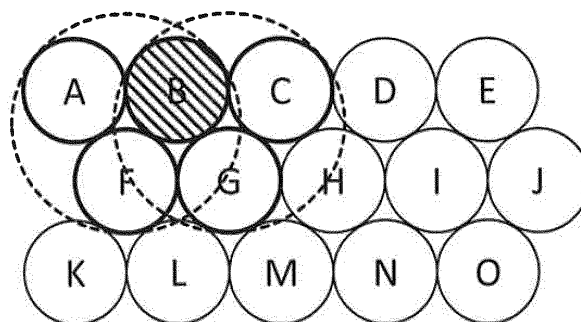


Fig.2A

Description

[0001] The invention relates to a multiple feeds per beam antenna array feed system using a quasi-periodic multi-port coupler, for example for use in satellite communication.

[0002] In feed systems using the multiple feeds per beam principle antenna beams, herein referred to as beams, are excited by a plurality of single antennas. Adjacent beams use at least one shared antenna of the single antennas which provides an overlap of the adjacent beams. In order to prevent mutual influence on the signals of adjacent beams, these beams must be orthogonal to each other. This mutual influence can be prevented by using orthogonal polarization. If a same polarization is used, it is necessary that a single antenna commonly used for adjacent beams has a coupler or coupling-network. A usage of usual 4-port couplers or 6-port couplers enforces orthogonality of excitation coefficient sets of commonly used antennas. This limits an optimal choice of the excitation coefficients and leads to degradation in antenna gain of typically 1 dB. This is typically called dual-mode or triple mode loss depending on a number of commonly used antennas.

[0003] Until now, feed systems are subject to disadvantages, such as multimode losses, excitation coefficients being either not freely and optimally selectable, beams not being practical for illuminating big areas without a gap, or a down-/upstream antenna array needing another reflector.

[0004] It is an object of the present invention to solve the technical problem of determining an optimal set of excitation coefficients for each beam and using a maximum power capability of the antenna array.

[0005] According to a first aspect, a multiple feeds per beam antenna array feed system using a quasi-periodic multi-port coupler comprises a quasi-periodic multi-port coupler and an antenna array. The quasi-periodic multi-port coupler is adapted and arranged to distribute power from an input port of at least two input ports to an output port corresponding to the input port and to two output ports adjacent to the output port corresponding to the input port. The antenna array is connected to the quasi-periodic multi-port coupler. The antenna array is further adapted and arranged to be fed by or to feed the quasi-periodic multi-port coupler. The antenna array is further adapted and arranged to transmit or receive at least two beams. The antenna array comprises a plurality of antennas. Each antenna of the plurality of antennas is adapted and arranged to transmit or receive an electromagnetic wave having a same polarization or orthogonal polarizations. A combination of electromagnetic waves transmitted or received by a subset of the plurality of antennas forms one of the at least two beams. Exactly one antenna of the subset is used as a common antenna with respect to two beams of the at least two beams to be transmitted or to be received by the antenna array. Exactly one antenna of the subset for each quasi-periodic

coupler may be used as the common/shared antenna with respect to two beams of the at least two beams to be transmitted or to be received by the antenna array.

[0006] The output ports of the quasi-periodic multi-port coupler may further be arranged, such that each of the output ports can feed one of the plurality of antennas of the antenna array. Further, the output ports may be further arranged and adapted to distribute the power. A part of the power may be outputted by two output ports of the plurality of output ports of the quasi-periodic multi-port coupler. The two output ports may be adapted and arranged to combine the part of the power up-/downstream the common antenna and to feed the antenna with the part of the power.

[0007] The antenna array may further be adapted and arranged to be fed by or to feed the quasi-periodic multi-port coupler, such that only one common antenna between adjacent beams exists, for example for each quasi-periodic coupler.

[0008] The two output ports adjacent to the input port's corresponding output port may be directly adjacent to the input port's corresponding output port.

[0009] The advantage of the quasi-periodic multi-port coupler is that a signal fed to one of the input ports can be directly received/transmitted to its corresponding output port and the directly adjacent output ports. The coupling effect on all other output ports beside the two directly adjacent output ports as well as unused input ports is negligible. Simultaneously the quasi-periodic multi-port coupler is able to isolate input signals fed to the at least two input ports.

[0010] The term "multi-port" can be understood as a port having at least 2 or more ports. The term "quasi-periodic" can be understood as periodic in a rough estimation, such that the coupling values of the quasi-periodic multi-port coupler have nearly the same values for each beam to be transmitted/received. Since the coupling values may differ from the exact same values for each coupling value, the term "quasi-periodic" may further be understood as an expression commonly used by a skilled person in the field of high frequency technology.

[0011] The term "common antenna" or "commonly used antenna" may be understood as the antenna being part of two beams. Further, the terms "common antenna" and "commonly used antenna" may also be referred to as "shared antenna". The term "beam" may be understood as an electromagnetic wave formed by more than one antenna. The term "multi-port" may be understood as having more than one port as an input port and/or output port. The term "multiple feeds" may be understood as having a number of waveguides being combined by a part the antenna array to a beam. The term "two beams of the at least two beams" may be understood that the exactly/only one antenna, for example per quasi-periodic multi-port coupler, of the subset is used as a common antenna with respect to exactly/only two beams of more than two beams, when more than two beams are to be transmitted or received by the antenna array.

[0012] The common antenna may only form part of two adjacent beams. The term "adjacent beams" may be understood as two beams spatially adjacent. The "plurality of antennas" may be understood as a number of antennas higher than three. The antennas can be horn antennas.

[0013] The quasi-periodic multi-port coupler may further be adapted and arranged to distribute power in a predetermined ratio from the input port of the at least two input ports to the output port corresponding to the input port and to the two output ports adjacent to the output port corresponding to the input port. The number of input ports of the quasi-periodic multi-port coupler may determine the number of beams of the quasi-periodic multi-port coupler.

[0014] The output port corresponding to the input port and the two output ports adjacent to the output port corresponding to the input port may form at least part of the multiple feeds.

[0015] The common antenna may be adapted and arranged to transmit electromagnetic waves corresponding to two different beams. The common antenna may be adapted and arranged to receive electromagnetic waves corresponding to two different beams.

[0016] The subset can have another common antenna. The other common antenna may not form part of more than two adjacent beams.

[0017] The other common antenna may be adapted and arranged to transmit electromagnetic waves corresponding to two different beams, when there are more than two beams to be transmitted. The other common antenna may be adapted and arranged to receive electromagnetic waves corresponding to two different beams, when there are more than two beams to be received.

[0018] The multiple feeds per beam antenna array feed system may further comprise at least two input sources. Each input source of the at least two input sources is connected to the at least two input ports. Each of the at least two input sources may be adapted and arranged to feed a different one of the at least two input ports.

[0019] The quasi-periodic multi-port coupler may have a negligible coupling effect on output ports different to the output port corresponding to the input port and to the two adjacent output ports as well as to the unused input ports.

[0020] The quasi-periodic multi-port coupler may be further adapted and arranged to isolate each of the at least two input ports.

[0021] The commonly used antenna may be adapted and arranged to transmit or receive an electromagnetic wave having a single polarization. The single polarization may be the same polarization as of the other antennas of the plurality of antennas.

[0022] The commonly used antenna may be adapted and arranged to transmit or receive a part of a first and second beam. The first and the second beam correspond to electromagnetic waves having the same polarization.

[0023] An advantage of the foregoing claims is that a gap between adjacent areas to be illuminated by the antenna array is closed, while maintaining a high gain with respect to commonly known horn antenna arrays with multiple feeds per beam.

[0024] The multiple feeds per beam antenna array feed system may be for use on a satellite. The term "use on a satellite" may be understood as being mounted on a satellite or being partly arranged within or at the satellite.

[0025] The satellite can be a Very High Throughput Satellite, VHTS.

[0026] The multiple feeds per beam antenna array feed system can further comprise another quasi-periodic multi-port coupler. The other quasi-periodic multi-port coupler can be connected to the antenna array. The other quasi-periodic multi-port coupler may further be adapted and arranged to be fed or to feed the antenna array. Also, the antenna array may further be adapted and arranged to be fed or to feed the other quasi-periodic multi-port coupler. Exactly two antennas of the subset can be used as common antennas with respect to three beams of the beams to be transmitted or to be received by the antenna array.

[0027] According to a second aspect, a satellite comprises the multiple feeds per beam antenna array feed system according to the first aspect.

[0028] Other objects, features, advantages and applications will become apparent from the following description of non-limiting embodiments with reference to the accompanying drawings. In the drawings, all described and/or illustrated features, alone or in any combination form the subject matter disclosed therein, irrespective of their grouping in the claims or their relations/references. The dimensions and proportions of components or parts shown in the figures are not necessarily to scale; these dimensions and proportions may differ from illustrations in the figures and implemented embodiments.

Figure 1 schematically illustrates an antenna array with an exemplary antenna arrangement;

Figure 2A schematically illustrates an excitation of 3 antennas per beam;

Figure 2B schematically illustrates an excitation of 3 antennas per beam with corresponding output ports;

Figure 3A schematically illustrates an excitation of 4 antennas per beam;

Figure 3B schematically illustrates an excitation of 4 antennas per beam with corresponding output ports;

Figure 4A schematically illustrates an excitation of 7 antennas per beam and one quasi periodic coupler;

Figure 4B schematically illustrates an excitation of 7 antennas per beam and one quasi periodic coupler with corresponding output ports; and

Figure 5 schematically illustrates an excitation of 7 antennas per beam and two quasi periodic couplers with corresponding output ports.

[0029] The variants of the functional and operational aspects as well as their functional and operational aspects described herein are only for a better understanding of its structure, its functions and properties; they do not limit the disclosure to the embodiments. The figures are partially schematic, said essential properties and effects are clearly shown enlarged in part in order to clarify the functions, active principles, embodiments and technical characteristics. Every operation, every principle, every technical aspect and every feature that/which is disclosed in the figures or in the text is/are able to be combined with all claims, each feature in the text and the other figures, other modes of operation, principles, technical refinements and features that are included in this disclosure, or result from it, so that all possible combinations are assigned to the devices and methods described. They also include combinations of all individual comments in the text, that is, in each section of the description, in the claims and combinations between different variations in the text, in the claims and in the figures, and can be made to subject-matter of further claims. The claims do not limit the disclosure and therefore the possible combinations of all identified characteristics among themselves. All features disclosed are explicitly also individually and in combination with all other features disclosed herein.

[0030] In the Figures herein, corresponding or functionally similar components are provided with the same or similar reference numerals.

[0031] In the following, without being restricted thereto, specific details are set forth to provide a thorough understanding of the present disclosure. However, it is clear to the skilled person that the present disclosure may be used in other embodiments, which may differ from the details set out below.

[0032] Figure 1 schematically illustrates a principal antenna allocation, herein below exemplified as horn allocation. There are 15 different allocations from A, B,..., O. A, B,..., O may also be referred to as the antenna element in this example. It can be even more than those 15 different allocations or less than 15 allocations. This principle illustration with these 15 different allocations has 3 different bullet possibilities of exciting a beam. There are beam clusters of 3, 4 or 7 elements. That means that a cluster of 3, 4 or 7 elements can excite a beam. That means that in this example beams can be generated from a cluster of 3, 4 or 7 horn antennas. In the example of a 3 elements cluster, the clusters referred to the illustration can be $C_{31} = (A, B, F)$; $C_{32} = (B, C, G)$; $C_{33} = (C, D, H)$;

$C_{34} = (D, E, I)$; $C_{35} = (K, F, L)$; $C_{36} = (L, G, M)$; $C_{37} = (M, H, N)$; $C_{38} = (N, I, O)$. B is a common element/antenna of C_{31} and C_{32} , and C is a common element/antenna of C_{32} and C_{33} , and D is a common element/antenna of C_{33} and C_{34} , and F is a common element/antenna of C_{31} and C_{35} , and G is a common element/antenna of C_{32} and C_{36} , and H is a common element/antenna of C_{33} and C_{37} , and I is a common element/antenna of C_{34} and C_{38} . In the example of a 4 elements cluster, the clusters referred to the illustration can be $C_{41} = (F, B, G, L)$; $C_{42} = (G, C, H, M)$; $C_{43} = (H, D, I, M)$; $C_{44} = (I, E, J, O)$ with G being a common element/antenna of C_{41} and C_{42} , and H being a common element/antenna of C_{42} and C_{43} , and I being a common element/antenna of C_{43} and C_{44} . In the example of a 7 elements cluster, the clusters referred to the illustration can be $C_{71} = (F, B, C, H, M, L, G)$; $C_{72} = (H, D, E, J, O, N, I)$ with H being a common element/antenna of C_{71} and C_{72} . "Common" may be understood as being shared by adjacent clusters generating/exciting an adjacent beam, wherein the common element is part of the generating of both adjacent beams.

[0033] Those antennas/elements of the illustration in figure 1 are part of the multiple feeds per beam antenna array feed system comprising a quasi-periodic multi-port coupler. The quasi-periodic multi-port coupler is adapted and arranged to distribute power from an input port of at least two input ports to the input port's corresponding output port and to two output ports adjacent to the input port's corresponding output port. The antenna array is connected to the quasi-periodic multi-port coupler based on the number of clusters. The antenna array is further adapted and arranged to be fed by or to feed the quasi-periodic multi-port coupler, such that only one common antenna between adjacent beams exist and that a beam is generated with a number of cluster elements according to a cluster prerequisite, for example a usage of a 3 elements cluster, 4-elements or 7-elements cluster. Other constellations of clusters are possible. The antenna array is further adapted and arranged to transmit at least two beams. These two beams might be referred to as electromagnetic beams have a specific polarization, such as linear, circular or elliptical polarization. The antenna array comprises a plurality of antennas. Each antenna of the plurality of antennas is adapted and arranged to transmit an electromagnetic wave having a same polarization, for example fed by the same quasi periodic coupler. This same polarization may be a linear, circular or elliptical polarization being the same for all antenna/horn elements, such as for A, B,..., O shown in figure 1. A combination of electromagnetic waves transmitted or received by a subset of the plurality of antennas forms one of the at least two beams. The subset might be referred to as the clusters and further illustrated in the following figures 2A, 3A and 4A for example. Exactly one antenna of the subset is used as a common antenna with respect to two beams of the at least two beams to be transmitted or received by the antenna array. In the example of a 3 elements cluster, the at least two beams to be transmitted

or received by the antenna array are 8 beams being excited by C_{31} , C_{32} , C_{33} , C_{34} , C_{35} , C_{36} , C_{37} , C_{38} . In the example of a 4 elements cluster, the at least two beams to be transmitted or received by the antenna array are four beams being excited by C_{41} , C_{42} , C_{43} , C_{44} . In the example of a 7 elements cluster, the at least two beams to be transmitted or received by the antenna array are two beams being excited by C_{71} and C_{72} .

[0034] Figure 2A schematically illustrates an example of a 3 elements cluster. A power is divided within the quasi-periodic multi-port coupler and provided/fed to the antenna elements illustrated in figure 2A. Multi-port means that there are multiple input and multiple output ports, wherein the number of the input ports and the number of the output ports can be different. It can even be one input port and multiple output ports.

[0035] An output port corresponding to the input port of the quasi-periodic multi-port coupler receives power from one of the input ports as well as two adjacent output ports referred to as adjacent output ports to the input ports corresponding output port. As an example, two clusters of elements with corresponding beams are illustrated in figure 2A. The clusters are $C_{31} = (A, B, F)$; $C_{32} = (B, C, G)$ in this example. The two excited beams share the common element B, wherein the cluster C_{31} generates/excites a first beam and C_{32} generates/excites a second beam. In figure 2A, there can be eight 3 elements clusters generating eight beams. This array is not limited to the 15 elements A, B,..., O. There can be less or even more elements/antennas. The same applies to the following figures below. In this example the element J does not play a role and could be omitted.

[0036] Figure 2B schematically illustrates the principle in a planar line diagram illustrating two beams B1 and B2. B1 is divided onto the antenna elements A, F and B; and B2 is divided onto the antenna elements B, G and C. A possible third beam would share the element C in this example.

[0037] Figure 3A schematically illustrates an example of a 4 elements cluster. A power is divided within the quasi-periodic multi-port coupler and provided/fed to the antenna elements illustrated in figure 3A. As an example, two clusters of elements with corresponding beams are illustrated in figure 3A. The clusters are $C_{41} = (F, B, G, L)$ and $C_{42} = (G, C, H, M)$ in this example. The two excited beams share the common element G, wherein the cluster C_{41} generates/excites a first beam and C_{42} generates/excites a second beam. In figure 3A, there can be four 4 elements clusters generating four beams. This array is not limited to the 15 elements A, B,..., O. There can be less or even more elements/antennas. The same applies to the following figures below. In this example the two elements A and K do not play a role and could be omitted.

[0038] Figure 3B schematically illustrates the principle in a planar line diagram illustrating two beams B1 and B2. B1 is divided onto the antenna elements F, B, G and L (illustrated in figure 3A); and B2 is divided onto the antenna elements G, C, H and M (illustrated in figure 3A).

A possible third beam would share the element H in this example. Antenna elements L and M respectively are fed by another coupler, in particular a four-port coupler. The four-port coupler can be upstream or downstream with respect to the quasi-periodic multi-port coupler.

[0039] Figure 4A schematically illustrates an example of a 7 elements cluster. A power is divided within the quasi-periodic multi-port coupler and provided/fed to the antenna elements illustrated in figure 4A. As an example, two clusters of elements with corresponding beams are illustrated in figure 4A. The clusters are $C_{71} = (F, B, C, H, M, L, G)$; $C_{72} = (H, D, E, J, O, N, I)$ in this example. The two excited beams share the common element H, wherein the cluster C_{71} generates/excites a first beam and C_{72} generates/excites a second beam. In figure 4A, there can be two 7 elements clusters generating two beams. This array is not limited to the 15 elements A, B,..., O. There can be less or even more elements/antennas. In this example the two elements A and K do not play a role and could be omitted.

[0040] Figure 4B schematically illustrates the principle in a planar line diagram illustrating two beams B1 and B2. B1 is divided onto the antenna elements F, G and H; and B2 is divided onto the antenna elements H, I, J. A possible third beam would share the element J in this example, when there are more elements on the right side as of figure 4A. Antenna elements B, C, L and M, and D, E, N and O respectively are fed by standard power dividers, in particular a four-port coupler, such as for example a 90° hybrid, a symmetrical power divider or a directional coupler. The power divider can be upstream or downstream with respect to the quasi-periodic multi-port coupler.

[0041] Figure 5 schematically illustrates an excitation of 7 antennas per beam and two quasi periodic couplers with corresponding output ports. Figure 5 shows the case, wherein two adjacent beams can be shared by two single antennas. The two shared single antennas can be fed by two different quasi-periodic multi-port couplers. In the case of figure 5, two 6-port couplers would be necessary to feed the antenna array. In the case of a first beam, a signal fed to the antenna array would be split onto ports P1, P4 and antenna D, which is illustrated as a horn, which may be a preferred antenna type in this scenario. In the case of a second beam, a signal fed to the antenna array would be split onto ports P2, P5 and antenna I. In the case of a third beam, a signal fed to the antenna array would be split onto ports P3, P6 and antenna N. Thereby, the first and second beams share two antennas, namely the antennas F and G. Further, the second and third beams share two antennas, namely the antennas K and L.

[0042] The invention is not limited in any way to the embodiments described above. On the contrary, there are many possibilities for modifications thereof, which are apparent to an average skilled person without departing from the underlying idea of the invention as defined in the appended claims.

Claims

1. Multiple feeds per beam antenna array feed system using a quasi-periodic multi-port coupler comprising:

a quasi-periodic multi-port coupler adapted and arranged to distribute power from an input port of at least two input ports to an output port corresponding to the input port and to two output ports adjacent to the output port corresponding to the input port; and

an antenna array connected to and adapted and arranged to be fed by or to feed the quasi-periodic multi-port coupler, and further adapted and arranged to transmit or to receive at least two beams, wherein the antenna array comprises a plurality of antennas, each antenna of the plurality of antennas being adapted and arranged to transmit or to receive an electromagnetic wave having a same polarization, wherein a combination of electromagnetic waves transmitted or received by a subset of the plurality of antennas forms one of the at least two beams, and wherein exactly one antenna of the subset is used as a common antenna with respect to two beams of the at least two beams to be transmitted or to be received by the antenna array.

2. Multiple feeds per beam antenna array feed system according to claim 1, wherein the power is distributed in a predetermined ratio.

3. Multiple feeds per beam antenna array feed system according to claims 1 or 2, wherein the output port corresponding to the input port and the two output ports adjacent to the output port corresponding to the input port form at least part of the multiple feeds.

4. Multiple feeds per beam antenna array feed system according to any one of the foregoing claims, wherein the common antenna is adapted and arranged to transmit or to receive electromagnetic waves corresponding to two different beams

5. Multiple feeds per beam antenna array feed system according to any one of the foregoing claims, wherein the subset has another common antenna, wherein the other common antenna does not form part of more than two adjacent beams.

6. Multiple feeds per beam antenna array feed system according to claim 6, wherein the other common antenna is adapted and arranged to transmit or to receive electromagnetic waves corresponding to two different beams, when there are more than two beams to be transmitted or to be received.

7. Multiple feeds per beam antenna array feed system

according to any one of the foregoing claims, further comprising:

at least two input sources each connected to the at least two input ports, wherein each of the at least two input sources is adapted and arranged to feed a different one of the at least two input ports.

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8. Multiple feeds per beam antenna array feed system according to any one of the foregoing claims, wherein the commonly used antenna is adapted and arranged to transmit or to receive an electromagnetic wave having a single polarization.

9. Multiple feeds per beam antenna array feed system according to any one of the foregoing claims, wherein the commonly used antenna is adapted and arranged to transmit or to receive a part of a first and second beam each corresponding to electromagnetic waves having the same polarization.

10. Multiple feeds per beam antenna array feed system according to any of the foregoing claims for use in a satellite.

11. Multiple feeds per beam antenna array feed system according to claim 10, wherein the satellite is a Very High Throughput Satellite, VHTS.

12. Multiple feeds per beam antenna array feed system according to any of the foregoing claims, further comprising:

another quasi-periodic multi-port coupler connected to the antenna array, wherein the other quasi-periodic multi-port coupler is adapted and arranged to be fed or to feed the antenna array, wherein exactly two antennas of the subset are used as a common antenna with respect to three beams of the beams to be transmitted or to be received by the antenna array.

13. Satellite with the multiple feeds per beam antenna array feed system according to any one of claims 1 to 12.

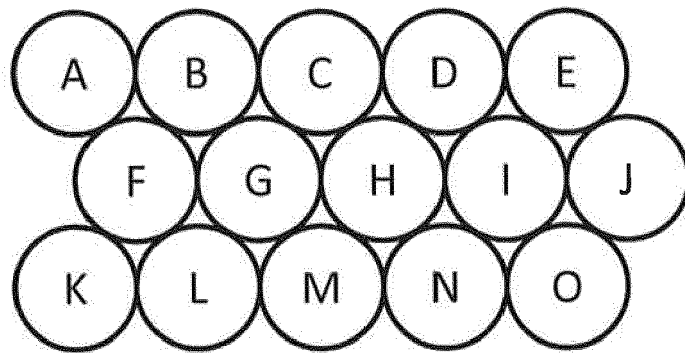


Fig.1

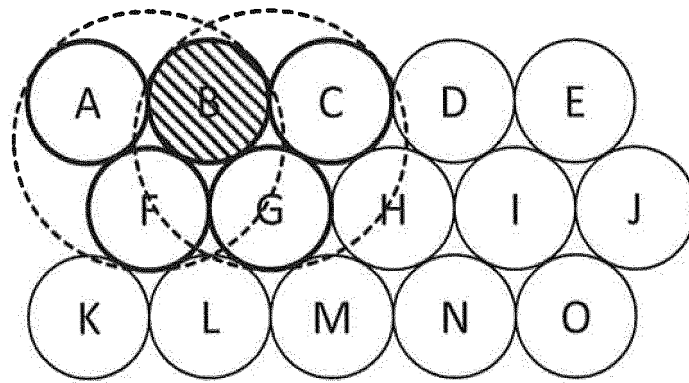


Fig.2A

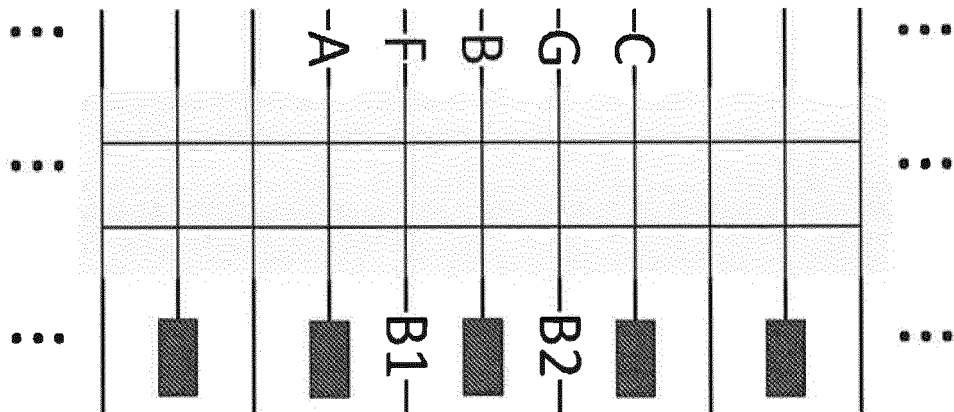


Fig.2B

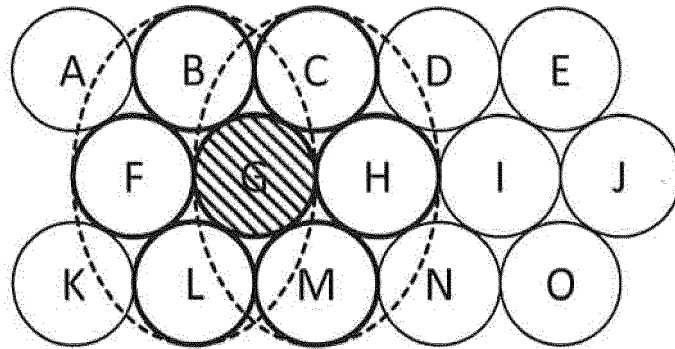


Fig.3A

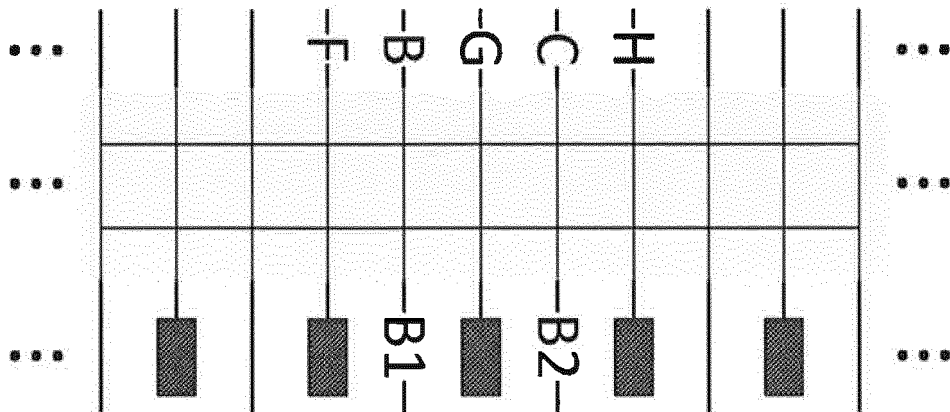


Fig.3B

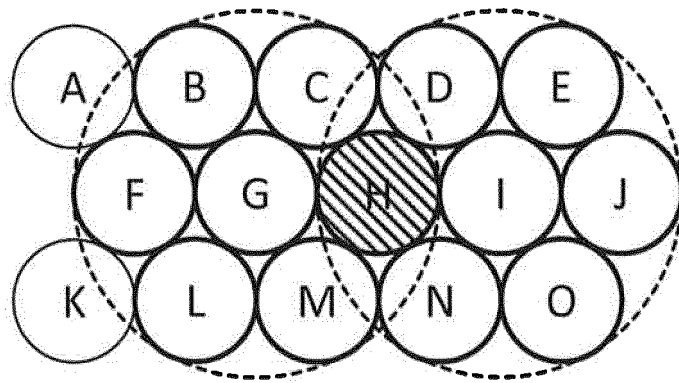


Fig.4A

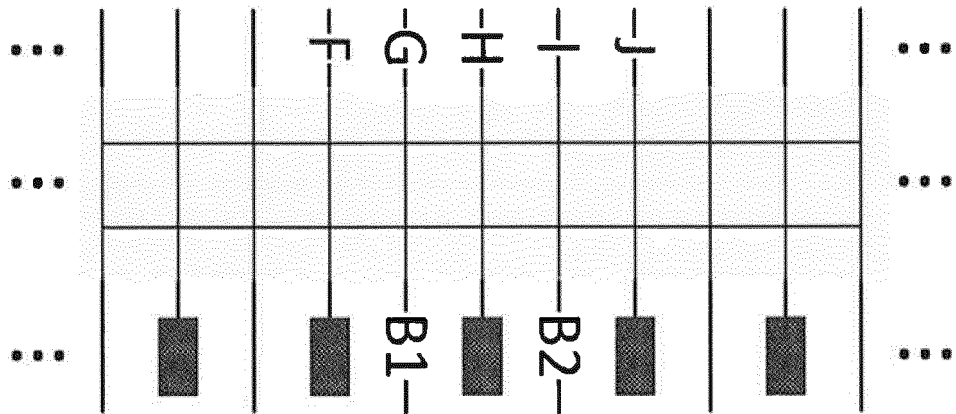


Fig.4B

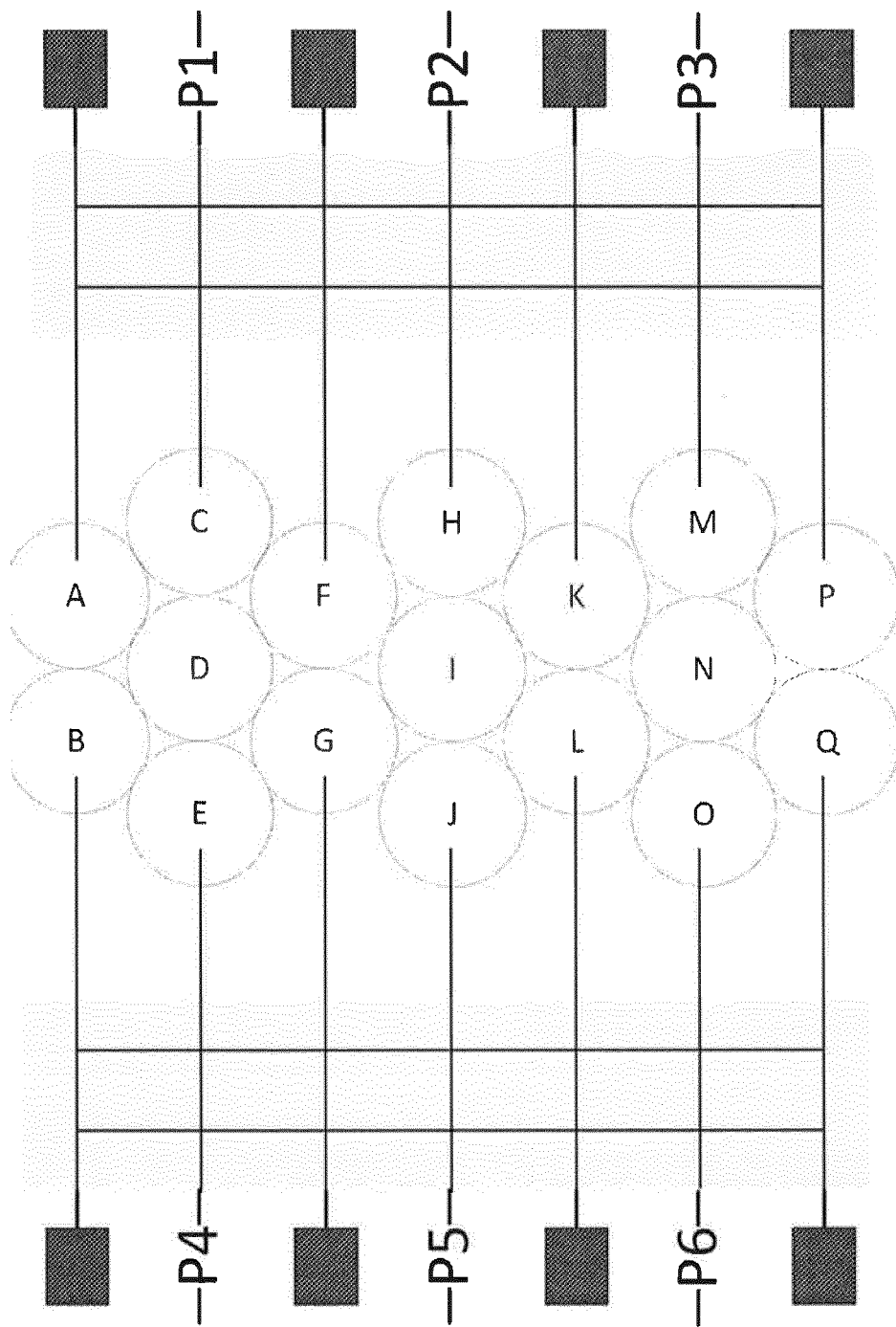


Fig.5



EUROPEAN SEARCH REPORT

Application Number
EP 16 18 4004

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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	US 4 236 161 A (OHM EDWARD A [US]) 25 November 1980 (1980-11-25) * column 1, line 7 - line 21 * * column 2, line 28 - line 55 * * column 4, line 17 - line 38 * * column 5, line 39 - column 6, line 12; figures 1-3 *	1-13	INV. H01Q1/28 H01Q19/17 H01Q25/00
X	EP 2 688 142 A1 (THALES SA [FR]) 22 January 2014 (2014-01-22) * figure 4 * * paragraph [0001] * * paragraph [0009] - paragraph [0010] * * paragraph [0027] - paragraph [0028] *	1-13	
X	EP 2 688 138 A1 (THALES SA [FR]) 22 January 2014 (2014-01-22) * figure all * * paragraph [0001] * * paragraph [0008] * * paragraph [0018] - paragraph [0021] *	1-4,7-13	
X	JP H06 85534 A (TOSHIBA CORP) 25 March 1994 (1994-03-25) * abstract *	1-4,7-9	TECHNICAL FIELDS SEARCHED (IPC) H01Q
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 31 January 2017	Examiner Wattiaux, Véronique
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 18 4004

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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31-01-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4236161	A	25-11-1980	NONE
EP 2688142	A1	22-01-2014	CA 2821250 A1 20-01-2014 EP 2688142 A1 22-01-2014 FR 2993716 A1 24-01-2014 JP 2014023162 A 03-02-2014 US 2014022138 A1 23-01-2014
EP 2688138	A1	22-01-2014	CA 2821242 A1 20-01-2014 EP 2688138 A1 22-01-2014 FR 2993715 A1 24-01-2014 JP 2014023163 A 03-02-2014 US 2014022137 A1 23-01-2014
JP H0685534	A	25-03-1994	NONE