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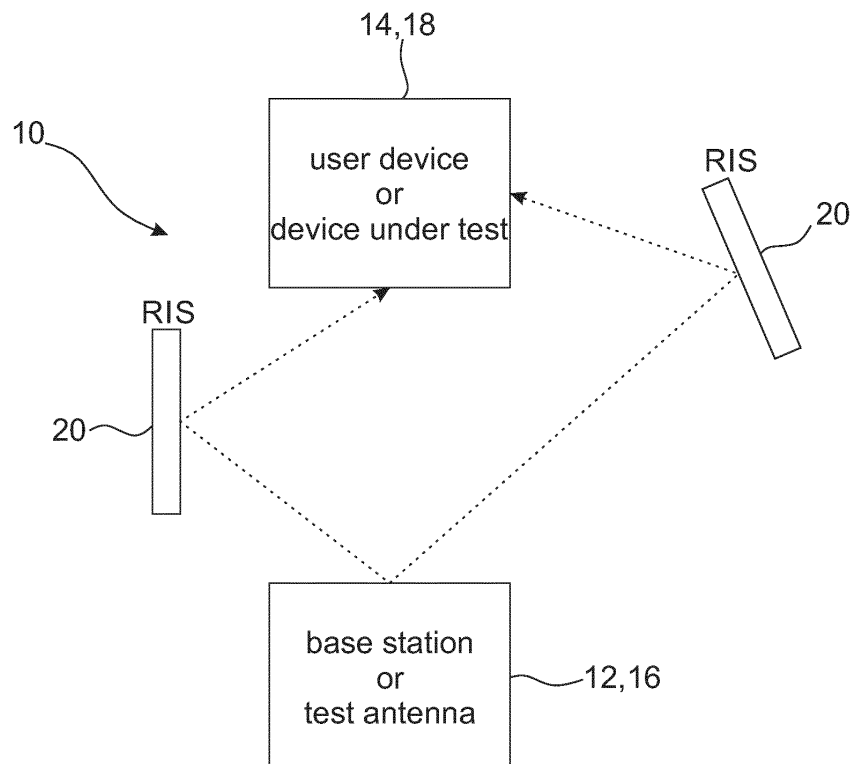
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RECONFIGURABLE INTELLIGENT SURFACE AND WIRELESS COMMUNICATION NETWORK

- (57)

A reconfigurable intelligent surface (20) for improving network performance is described. The reconfigurable intelligent surface (20) comprises a plurality of first antenna elements and a plurality of second antenna elements. The first antenna elements are linear polarization antennas having first polarization planes being parallel to each other. The second antenna elements are
- linear polarization antennas having second polarization planes being parallel to each other. Each of the first polarization planes intersects each of the second polarization planes. The first antenna elements and the second antenna elements are arranged offset to each other. Further, a wireless communication network (10) is described.

Fig. 1



Description

[0001] The invention generally relates to a reconfigurable intelligent surface for improving network performance. The invention further relates to a wireless communication network.

[0002] Reconfigurable intelligent surfaces (RISs) are an emerging technology that can be used in wireless communication networks in order to enhance the performance of the wireless communication network.

[0003] Usually, such RISs comprise a plurality of antenna elements, wherein the individual antenna elements can be configured such that desired reflection properties of the RIS are obtained.

[0004] For example, at least one resistance of the individual antenna elements and/or at least one capacitance of the individual antenna elements may be adapted in order to obtain the desired reflection properties of the RIS.

[0005] However, it has turned out that manufacturing dual-polarized RISs, i.e. RISs with reflection properties that can be adapted separately for two different polarizations of incident electromagnetic waves, is rather challenging and costly.

[0006] Thus, the object of the present invention is to provide a dual-polarized RIS that is easier and more cost-efficient to manufacture.

[0007] According to the present invention, the problem is solved by a reconfigurable intelligent surface for improving network performance. The reconfigurable intelligent surface comprises a plurality of first antenna elements and a plurality of second antenna elements. The first antenna elements are linear polarization antennas having first polarization planes being parallel to each other. The second antenna elements are linear polarization antennas having second polarization planes being parallel to each other. Each of the first polarization planes intersects each of the second polarization planes. The first antenna elements and the second antenna elements are arranged offset to each other.

[0008] Therein and in the following, the term "parallel" is understood to denote truly parallel and/or identical planes. Accordingly, the first polarization planes may be pairwise truly parallel to each other, and/or pairwise identical. Likewise, the second polarization planes may be pairwise truly parallel to each other, and/or pairwise identical.

[0009] Further, the term "offset to each other" is understood to denote that centers of the individual antenna elements are pairwise different from each other. In other words, the centers of the individual antenna elements are distributed over the RIS such that, seen in a direction that is perpendicular to the RIS, the centers of different antenna elements do not coincide.

[0010] The invention is based on the idea to provide two different types of antenna elements, namely the first antenna elements and the second antenna elements, having two different polarization planes. Accordingly, the

antenna elements being associated with different polarizations can be controlled independent of each other, i.e. the first antenna elements can be controlled independent of the second antenna elements.

[0011] In other words, instead of providing dual-polarized antenna elements having two polarization planes, respectively, the two different types of antenna elements are provided on the RIS.

[0012] As single-polarization antenna elements are considerably more cost-efficient and considerably easier to manufacture than dual-polarization antenna elements, the RIS according to the present invention is easier and more cost-efficient to manufacture.

[0013] Moreover, it has turned out that the performance of the RIS with respect to the two linear polarizations associated with the first polarization planes and the second polarization planes is essentially unaffected by the offsets of the antenna elements with respect to each other.

[0014] Thus, the RIS according to the present invention provides high cross-polarization discrimination while being considerably easier and more cost-efficient to manufacture than RISs with dual-polarization antenna elements.

[0015] The reflectivity of the individual antenna elements may be adaptable such that desired reflectivity properties of the RIS are obtained. For example, at least one resistance of the individual antenna elements and/or at least one capacitance of the individual antenna elements may be adapted in order to obtain the desired reflection properties of the RIS.

[0016] In other words, for each antenna element, the reflection coefficient in a certain direction, amplitudes of reflected electromagnetic waves and/or phases of reflected electromagnetic waves can be adapted by adapting the reflectivity of the individual antenna elements, particularly by adapting the at least one resistance of the individual antenna elements and/or the at least one capacitance of the individual antenna elements.

[0017] Particularly, the reflectivities of the first antenna elements and the reflectivities of the second antenna elements can be adapted independent of each other, such that the reflectivity properties of the RIS with respect to the two different polarizations can be controlled independent of each other.

[0018] In fact, the RIS according to the present invention may allow for independent beamforming of electromagnetic waves having two different polarizations.

[0019] According to an aspect of the present invention, the first antenna elements and the second antenna elements are arranged according to a predefined pattern. The predefined pattern may be a repeating pattern or a non-repeating pattern. In general, any suitable pattern may be used.

[0020] Preferably, the predefined pattern has a symmetry with respect to the locations of the first antenna elements and the second antenna elements, such that the reflectivity properties of the RIS with respect to the

two different polarizations are equal.

[0021] Particularly, the first antenna elements may be arranged according to a first predefined pattern, and the second antenna elements may be arranged according to a second predefined pattern. The first predefined pattern may be equal to the second predefined pattern, such that the first antenna elements and the second antenna elements are arranged according to the same predefined pattern, but offset to each other.

[0022] According to another aspect of the present invention, the predefined pattern is a checkered pattern. In other words, the antenna elements may be arranged in rows and columns. Therein, the first antenna elements and the second antenna elements alternate in each row and in each column.

[0023] In other words, the first antenna elements and the second antenna elements may be arranged in an interleaved manner.

[0024] Particularly, distances between next-neighbor antenna elements may be constant. Accordingly, the first antenna elements and the second antenna elements may be evenly distributed over the RIS.

[0025] In an embodiment of the present invention, the first polarization planes and the second polarization planes enclose a predefined angle, particularly wherein the predefined angle is at least 30°. For example, the predefined angle may be chosen to match polarizations planes being employed by a wireless communication network, resulting in an optimal enhancement of the network performance.

[0026] Particularly, the predefined angle is 45° or 90°. However, it is to be understood that other predefined angles are possible.

[0027] In a further embodiment of the present invention, the first antenna elements and/or the second antenna elements partially overlap with each other seen in a direction being perpendicular to the reconfigurable intelligent surface. Thus, the distances between the individual antenna elements are smaller compared to a case where the first antenna elements and the second antenna elements are overlap-free. Accordingly, the number of antenna elements per area may be increased.

[0028] According to an aspect of the present invention, the first antenna elements and the second antenna elements are overlap-free seen in a direction being perpendicular to the reconfigurable intelligent surface. This allows for a highly symmetrical placement of the first antenna elements and the second antenna elements, resulting in a high cross polarization discrimination of the RIS due to the symmetrical structure of the RIS.

[0029] Shielding members may be provided between the first antenna elements and the second antenna elements, wherein the shielding members are configured to prevent electromagnetic waves from propagating between the antenna elements. Accordingly, undesired interactions between the different antenna elements are prevented by means of the shielding members.

[0030] Particularly, the shielding members are estab-

lished as metal walls and/or as via fences. For example, the first antenna elements and the second antenna elements may be provided on and/or in a substrate. Accordingly, the metal walls and/or the via fences may be provided on and/or in the substrate.

[0031] In an embodiment of the present invention, the reconfigurable intelligent surface comprises a first layer and a second layer, wherein the first layer is stacked on top of the second layer, wherein the first layer comprises the first antenna elements, and wherein the second layer comprises the second antenna elements. This way, the RIS is particularly easy and cost-efficient to manufacture, as the different types of antenna elements, i.e. the first antenna elements and the second antenna elements, can be manufactured independently of each other.

[0032] For example, the first layer comprising the first antenna elements and the second layer comprising the second antenna elements may be manufactured independent of each other. Afterwards, the first layer may be stacked on top of the second layer, e.g. by means of an adhesive layer.

[0033] Optionally, an intermediate layer may be provided between the first layer and the second layer, wherein the intermediate layer consists of a non-conducting material or a non-conducting combination of materials.

[0034] A further aspect of the present invention provides that the reconfigurable intelligent surface is integrated into a printed circuit board. The first antenna elements and the second antenna elements may be provided in the same layer of the printed circuit board or in different layers of the printed circuit board.

[0035] The shielding members described above may be provided in and/or on the printed circuit board, particularly wherein the shielding members are established as via fences.

[0036] The number of first antenna elements may be equal to the number of second antenna elements. Thus, the RIS provides high cross polarization discrimination due to the symmetrical structure with respect to the first antenna elements and the second antenna elements.

[0037] According to an aspect of the present invention, the first antenna elements and the second antenna elements are configured to reflect electromagnetic waves in a predetermined frequency range, particularly in a frequency range associated with 5G New Radio. In other words, the RIS may be adapted to improve the performance of a particular type of wireless communication network employing a particular frequency range.

[0038] According to the present invention, the problem further is solved by a wireless communication network. The wireless communication network comprises at least one transceiver device being configured to transmit and receive electromagnetic waves. The wireless communication network comprises at least one reconfigurable intelligent surface described above.

[0039] Particularly, the wireless communication network may be a 5G New Radio network. However, it is to be understood that the wireless communication network

may be established as another type of wireless communication network.

[0040] For example, the wireless communication network may be an over-the-air (OTA) test system. Accordingly, the wireless communication network may comprise at least one test antenna being configured to transmit and/or receive electromagnetic waves in order to test a device under test. One or several RISs described above may be arranged in the wireless communication network in order to redirect the electromagnetic waves between the device under test and the at least one test antenna in a predetermined manner.

[0041] Regarding the further advantages and properties of the wireless communication network, reference is made to the explanations given above with respect to the reconfigurable intelligent surface, which also hold for the wireless communication network and vice versa.

[0042] An aspect of the present invention provides that the at least one transceiver device comprises a base station and/or a user device. For example, the at least one RIS described above may be arranged in the wireless communication network such that the communication between the base station and the user device is facilitated, i.e. the range may be extended and/or the signal quality of transmissions between the base station and the user device may be enhanced.

[0043] The foregoing aspects and many of the attendant advantages of the claimed subject matter will become more readily appreciated as the same become better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

- Figure 1 schematically shows a wireless communication network according to the present invention;
- Figure 2 schematically shows a first variant of a reconfigurable intelligent surface according to the present invention;
- Figure 3 schematically shows a second variant of a reconfigurable intelligent surface according to the present invention;
- Figure 4 schematically shows a portion of the reconfigurable intelligent surface of Figure 2 in more detail; and
- Figure 5 schematically shows a cross section through the reconfigurable intelligent surface of Figure 2.

[0044] The detailed description set forth below in connection with the appended drawings, where like numerals reference like elements, is intended as a description of various embodiments of the disclosed subject matter and is not intended to represent the only embodiments. Each embodiment described in this disclosure is provided

merely as an example or illustration and should not be construed as preferred or advantageous over other embodiments. The illustrative examples provided herein are not intended to be exhaustive or to limit the claimed subject matter to the precise forms disclosed.

[0045] For the purposes of the present disclosure, the phrase "at least one of A, B, and C", for example, means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C), including all further possible permutations when more than three elements are listed. In other words, the term "at least one of A and B" generally means "A and/or B", namely "A" alone, "B" alone or "A and B".

[0046] Figure 1 schematically shows a wireless communication network 10. In general, the wireless communication network 10 may comprise a plurality of transceiver devices that are configured to communicate with each other via electromagnetic waves being transmitted and received by the individual transceiver devices.

[0047] For example, the wireless communication network 10 may be a 5G New Radio communication network comprising at least one base station 12 and at least one user device 14.

[0048] Thus, in this case the plurality of transceiver devices comprises the at least one base station 12 and the at least one user device 14.

[0049] For example, the user device 14 may be established as a smart phone, as a laptop, as a tablet, or as any other type of device being configured to communicate via 5G New Radio.

[0050] In another example, the wireless communication network 10 is established as an over-the-air (OTA) test system comprising at least one test antenna 16 and a device under test 18.

[0051] Thus, in this case the plurality of transceiver devices comprises the test antenna 16 and the at least one device under test 18.

[0052] Therein, the at least one test antenna 16 is configured to transmit and/or receive electromagnetic waves in order to test properties of the device under test 18.

[0053] In the following, the exemplary case of the wireless communication network 10 being established as a 5G New Radio communication network is described without restriction of generality. It is to be understood that the explanations provided in the following likewise apply to other types of communication networks, particularly to the OTA test system.

[0054] The wireless communication network 10 comprises at least one reconfigurable intelligent surface (RIS) 20, particularly a plurality of RISs 20.

[0055] In general, the at least one RIS 20 is configured to reflect electromagnetic waves in a predefined frequency range in a predetermined manner, such that the network performance of the wireless communication network 10 is enhanced.

[0056] In fact, the reflection coefficient of the at least one RIS 20 in a certain direction, amplitudes of reflected electromagnetic waves and/or phases of reflected electromagnetic waves can be controlled such that the net-

work performance of the wireless communication network 10 is enhanced.

[0057] In fact, the at least one RIS 20 may be arranged in the wireless communication network 10 and may be configured such that the communication between the base station 12 and the user device 14 is facilitated, i.e. the range may be extended and/or the signal quality of transmissions between the base station 12 and the user device 14 may be enhanced.

[0058] Figure 2 schematically shows a top view of the at least one RIS 20.

[0059] The RIS 20 comprises a plurality of first antenna elements 22 and a plurality of second antenna elements 24, wherein the centers of the first antenna elements 22 and the centers of the second antenna elements 24 are arranged offset to each other.

[0060] The individual antenna elements 22, 24 may also be called "unit cells".

[0061] The first antenna elements 22 are linear polarization antennas having first polarization planes being parallel to each other, i.e. the polarization planes of the first antenna elements 22 are pairwise truly parallel and/or pairwise identical.

[0062] Particularly, the first polarization planes are perpendicular to the RIS 20.

[0063] The second antenna elements 24 are linear polarization antennas having second polarization planes being parallel to each other, i.e. the polarization planes of the second antenna elements 24 are pairwise truly parallel and/or pairwise identical.

[0064] Particularly, the second polarization planes are perpendicular to the RIS 20.

[0065] The first antenna elements 22 and the second antenna elements may be established as any suitable type of antenna, respectively. Particularly, the antenna elements 22, 24 may be established as dipole antennas, respectively,

[0066] In Figure 2, an exemplary first polarization plane and an exemplary second polarization planes are indicated by the dotted lines labelled "P1" and "P2", respectively.

[0067] Therein, each of the first polarization planes intersects each of the second polarization planes at a predefined angle, which is indicated by the angle α in Figure 2.

[0068] In the particular example shown in Figure 2, the predefined angle is 90° , i.e. the first polarization planes and the second polarization planes are perpendicular to each other.

[0069] However, it is to be understood that the predefined angle may have any other suitable value. For example, the predefined angle may be 30° , 45° , or 60° .

[0070] The first antenna elements 22 and the second antenna elements 24 are arranged in a checkered pattern. More precisely, the centers of the first antenna elements 22 and the centers of the second antenna elements 24 are arranged in a checkered pattern.

[0071] Accordingly, the first antenna elements 22 and

the second antenna elements 24 are arranged in rows and columns, wherein the first antenna elements 22 and the second antenna elements 24 alternate in each row and in each column.

[0072] Therein, the number of first antenna elements 22 and the number of second antenna elements 24 may be equal.

[0073] However, it is to be understood that the first antenna elements 22 and the second antenna elements 24 may be arranged in any other suitable repeating or non-repeating pattern.

[0074] In the exemplary embodiment shown in Figure 2, the first antenna elements 22 and the second antenna elements 24 are overlap-free seen in a direction being perpendicular to the RIS 20.

[0075] In an alternative embodiment shown in Figure 3, the first antenna elements 22 and/or the second antenna elements 24 may partially overlap with each other seen in a direction being perpendicular to the RIS 20.

[0076] Figure 4 schematically shows a portion of the RIS 20 of Figure 2 in more detail. However, it is to be understood that the explanations given in the following likewise apply to the RIS 20 shown in Figure 3'.

[0077] As is illustrated in Figure 4, the first antenna elements 22 and the second antenna elements 24 may comprise at least one resistive element 26 having an adaptable resistance R and at least one capacitive element 28 having an adaptable capacitance C, respectively.

[0078] The at least one resistive element 26 and the at least one capacitive element 28 connect conducting portions 29 with each other.

[0079] For example, the conducting portions 29 may be established as a metal strip, respectively.

[0080] Control connections 30 may be provided, wherein the resistances R and/or the capacitances C of the antenna elements 22, 24 may be adaptable via the control connections 30, such that desired reflectivity properties of the RIS 20 are obtained.

[0081] For example, the wireless communication network 10 may comprise a control module, wherein the control module is connected with the control connections 30, and wherein the control module is configured to adapt the resistances R and/or the capacitances C of the antenna elements 22, 24 by selectively providing corresponding control signals to the antenna elements 22, 24.

[0082] As is further illustrated in Figure 4, the first antenna elements 22 and the second antenna elements 24 may be provided on a top side of a common substrate 32, particularly wherein the control connections 30 extend from a bottom side of the substrate through the substrate 32 to the antenna elements 22, 24.

[0083] The substrate 32 may consist of any electrically insulating material or an electrically insulating combination of materials.

[0084] Figure 5 shows a cross section through a further exemplary embodiment of the RIS 20, wherein the RIS 20 comprises several layers. For example, the RIS 20

may be established as a printed circuit board comprising several layers, wherein the antenna elements 22, 24 are embedded in the printed circuit board.

[0085] In the exemplary embodiment shown in Figure 5, the first antenna elements 22 are provided in a first layer 34, and the second antenna elements 24 are provided in a second layer 36 of the RIS 20.

[0086] Between the first layer 34 and the second layer 36, an intermediate layer 38 may be provided, particularly wherein the intermediate layer 38 may be attached to the first layer 34 and to the second layer 36 by means of an adhesive layer, respectively.

[0087] In general, the intermediate layer 38 may consist of any suitable electrically insulating material or combination of materials.

[0088] Further, a base layer 40 may be provided, wherein the second layer 36 may be attached to the base layer 40 via a further adhesive layer.

[0089] In general, the base layer 40 may consist of any suitable electrically insulating material or combination of materials.

[0090] As is illustrated in Figure 5, the control connections 30 may extend from a bottom side of the RIS 20, particularly from a bottom side of the base layer 40, through the RIS 20 to the respective antenna element 22, 24.

[0091] As is further illustrated in Figure 5, the RIS 20 may comprise shielding members 42 that are provided between the first antenna elements 22 and/or between the second antenna elements 24.

[0092] In general, the shielding members 42 are configured to shield the antenna elements 22, 24 from each other, such that electromagnetic waves are prevented from propagating between the antenna elements 22, 24.

[0093] For example, the shielding members 42 may be established as metal walls, respectively.

[0094] Alternatively, the shielding members 42 may be established as via fences, respectively.

[0095] However, it is also conceivable that one or several shielding members 42 are established as metal walls, while the remaining shielding members 42 are established as via fences.

[0096] Certain embodiments disclosed herein, particularly the respective module(s) and/or unit(s), utilize circuitry (e.g., one or more circuits) in order to implement standards, protocols, methodologies or technologies disclosed herein, operably couple two or more components, generate information, process information, analyze information, generate signals, encode/decode signals, convert signals, transmit and/or receive signals, control other devices, etc. Circuitry of any type can be used.

[0097] In an embodiment, circuitry includes, among other things, one or more computing devices such as a processor (e.g., a microprocessor), a central processing unit (CPU), a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a system on a chip (SoC), or the like, or any combinations thereof, and can include

discrete digital or analog circuit elements or electronics, or combinations thereof. In an embodiment, circuitry includes hardware circuit implementations (e.g., implementations in analog circuitry, implementations in digital circuitry, and the like, and combinations thereof).

[0098] In an embodiment, circuitry includes combinations of circuits and computer program products having software or firmware instructions stored on one or more computer readable memories that work together to cause a device to perform one or more protocols, methodologies or technologies described herein. In an embodiment, circuitry includes circuits, such as, for example, microprocessors or portions of microprocessor, that require software, firmware, and the like for operation. In an embodiment, circuitry includes one or more processors or portions thereof and accompanying software, firmware, hardware, and the like.

[0099] The present application may reference quantities and numbers. Unless specifically stated, such quantities and numbers are not to be considered restrictive, but exemplary of the possible quantities or numbers associated with the present application. Also in this regard, the present application may use the term "plurality" to reference a quantity or number. In this regard, the term "plurality" is meant to be any number that is more than one, for example, two, three, four, five, etc. The terms "about", "approximately", "near" etc., mean plus or minus 5% of the stated value.

Claims

1. A reconfigurable intelligent surface for improving network performance, the reconfigurable intelligent surface (20) comprising a plurality of first antenna elements (22) and a plurality of second antenna elements (24),

wherein the first antenna elements (22) are linear polarization antennas having first polarization planes being parallel to each other, wherein the second antenna elements (24) are linear polarization antennas having second polarization planes being parallel to each other, wherein each of the first polarization planes intersects each of the second polarization planes, and

wherein the first antenna elements (22) and the second antenna elements (24) are arranged offset to each other.

2. The reconfigurable intelligent surface of claim 1, wherein the first antenna elements (22) and the second antenna elements (24) are arranged according to a predefined pattern.
3. The reconfigurable intelligent surface of claim 2, wherein the predefined pattern is a checkered pat-

tern.

4. The reconfigurable intelligent surface according to any one of the preceding claims, wherein the first polarization planes and the second polarization planes enclose a predefined angle, particularly wherein the predefined angle is at least 30°. 5
5. The reconfigurable intelligent surface according to claim 4, wherein the predefined angle is 45° or 90°. 10
6. The reconfigurable intelligent surface according to any one of the preceding claims, wherein the first antenna elements (22) and/or the second antenna elements (24) partially overlap with each other seen in a direction being perpendicular to the reconfigurable intelligent surface (20). 15
7. The reconfigurable intelligent surface according to any one of claims 1 to 5, wherein the first antenna elements (22) and the second antenna elements (24) are overlap-free seen in a direction being perpendicular to the reconfigurable intelligent surface (20). 20
8. The reconfigurable intelligent surface according to any one of the preceding claims, wherein shielding members (42) are provided between the first antenna elements (22) and the second antenna elements (24), wherein the shielding members (42) are configured to prevent electromagnetic waves from propagating between the antenna elements (22, 24). 25 30
9. The reconfigurable intelligent surface according to claim 8, wherein the shielding members (42) are established as metal walls and/or as via fences. 35
10. The reconfigurable intelligent surface according to any one of the preceding claims, wherein the reconfigurable intelligent surface (20) comprises a first layer (34) and a second layer (36), wherein the first layer (34) is stacked on top of the second layer (36), wherein the first layer (34) comprises the first antenna elements (22), and wherein the second layer (36) comprises the second antenna elements (24). 40 45
11. The reconfigurable intelligent surface according to any one of the preceding claims, wherein the reconfigurable intelligent surface (20) is integrated into a printed circuit board. 50
12. The reconfigurable intelligent surface according to any one of the preceding claims, wherein the number of first antenna elements (22) is equal to the number of second antenna elements (24). 55
13. The reconfigurable intelligent surface according to any one of the preceding claims, wherein the first antenna elements (22) and the second antenna el-

ements (24) are configured to reflect electromagnetic waves in a predetermined frequency range, particularly in a frequency range associated with 5G New Radio.

14. A wireless communication network, wherein the wireless communication network (10) comprises at least one transceiver device being configured to transmit and receive electromagnetic waves, and wherein the wireless communication network comprises at least one reconfigurable intelligent surface (20) according to any one of the preceding claims.
15. The wireless communication network of claim 14, wherein the at least one transceiver device comprises a base station (12) and/or a user device (14).

Fig. 1

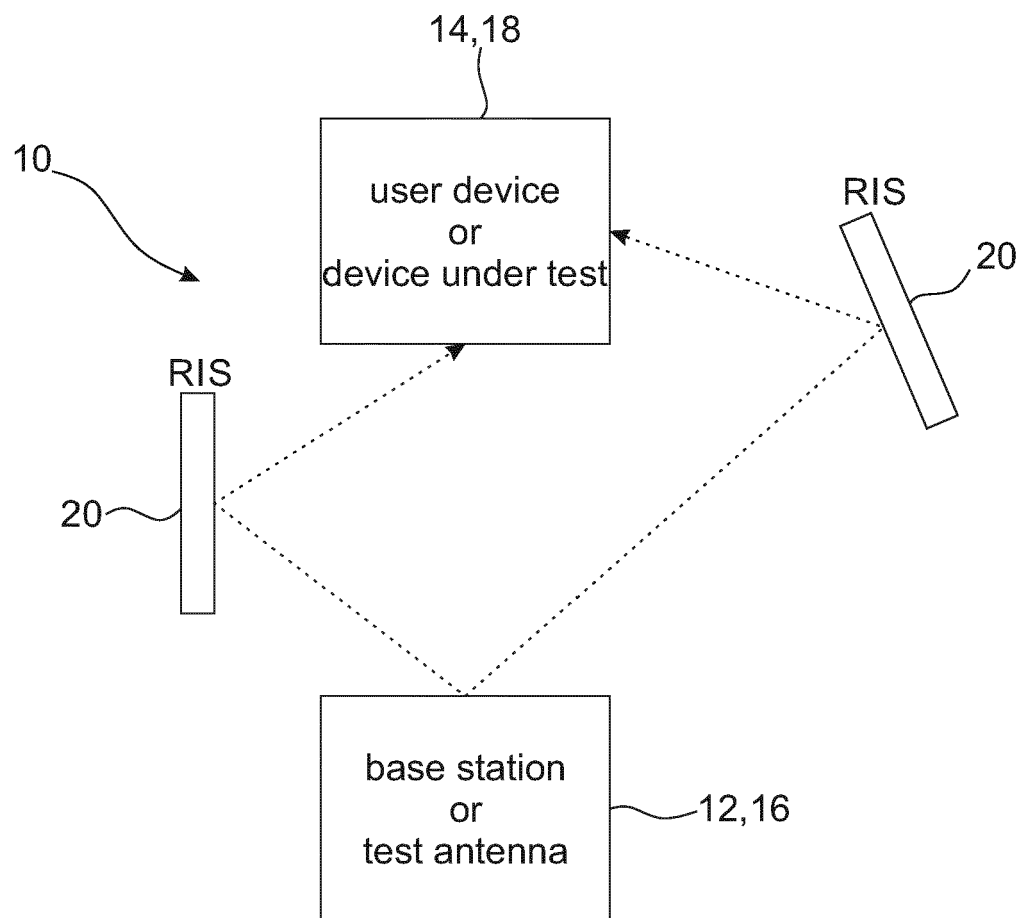


Fig. 2

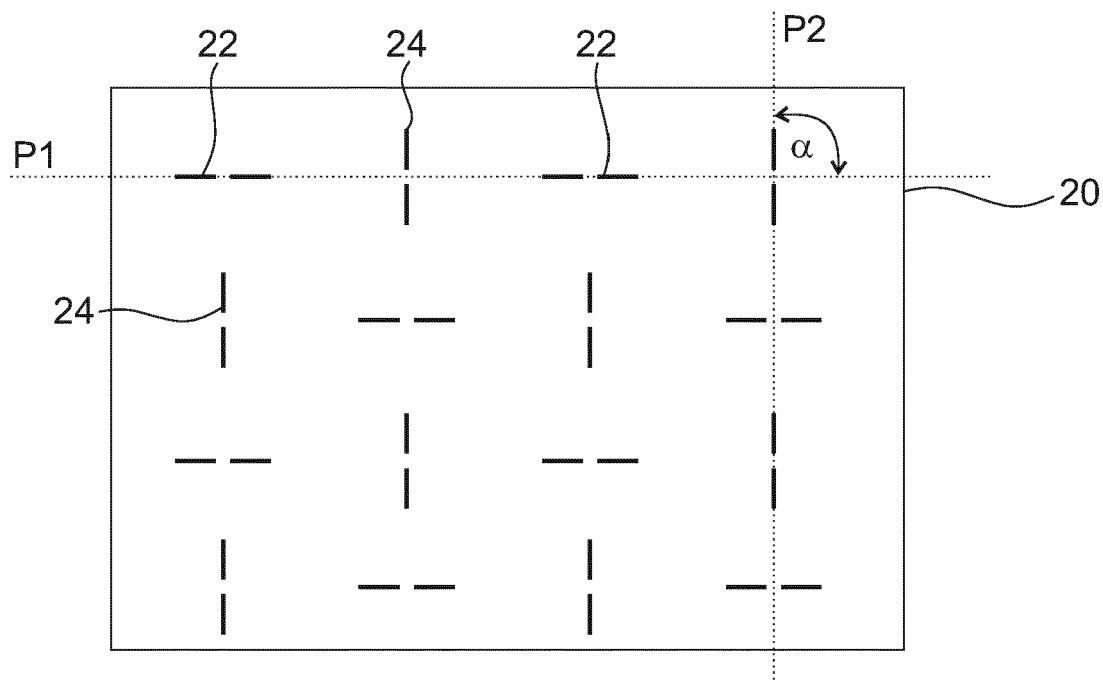


Fig. 3

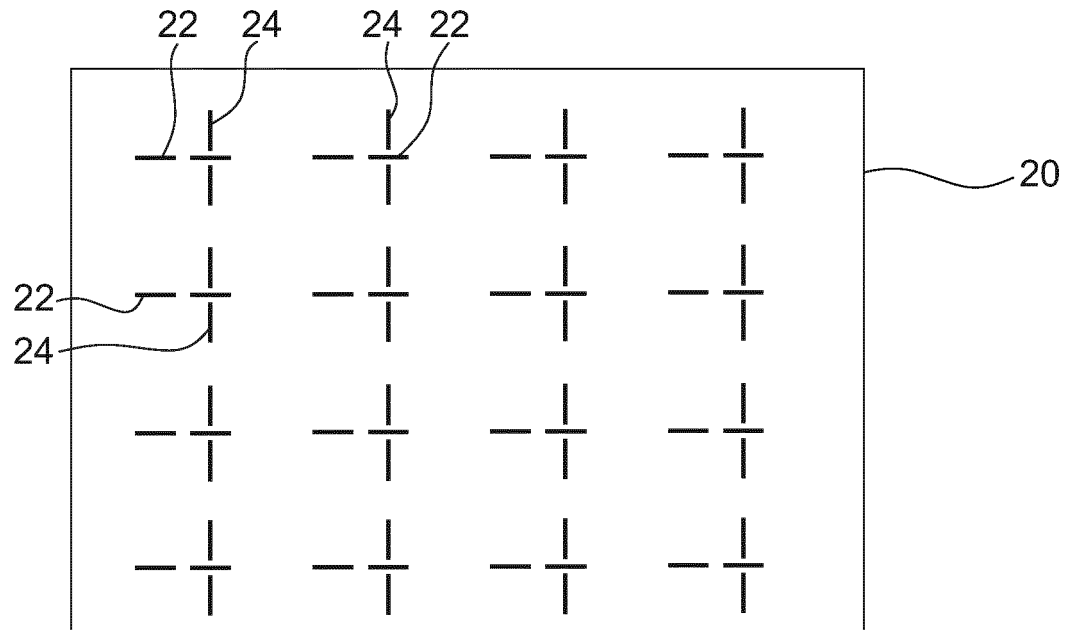


Fig. 4

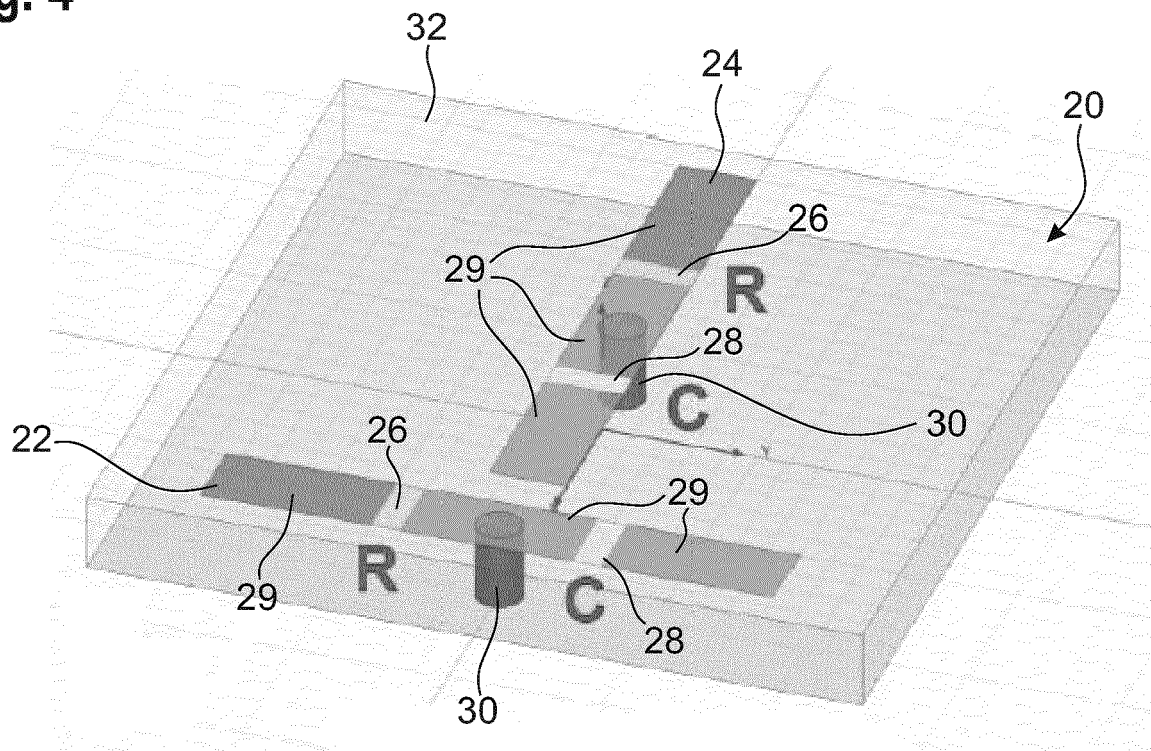
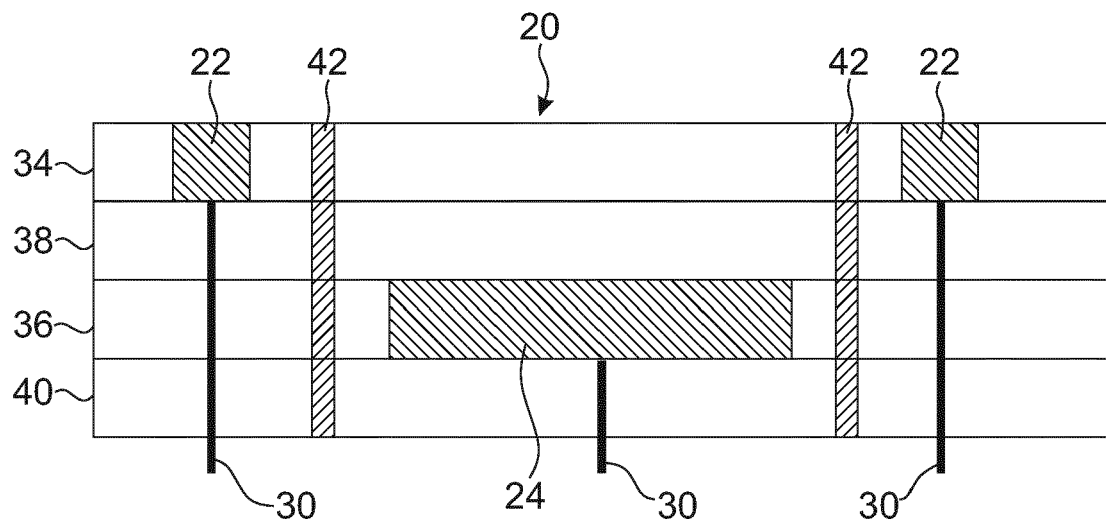


Fig. 5





EUROPEAN SEARCH REPORT

Application Number

EP 23 15 4064

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EPO FORM 1503 03:82 (P04C01)

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	CHEN XIANGYU ET AL: "Design and Implementation of MIMO Transmission Based on Dual-Polarized Reconfigurable Intelligent Surface", IEEE WIRELESS COMMUNICATIONS LETTERS, IEEE, PISCATAWAY, NJ, USA, vol. 10, no. 10, 6 July 2021 (2021-07-06), pages 2155-2159, XP011881671, ISSN: 2162-2337, DOI: 10.1109/LWC.2021.3095172 [retrieved on 2021-10-05]	1-5, 7, 11-15	INV. H01Q1/52 H01Q3/46 H01Q15/00
Y	* page 2155 - page 2159; figures 1,2 * -----	6,8-10	
Y	US 2017/179596 A1 (DIAZ RAFAEL FLORENCIO [ES] ET AL) 22 June 2017 (2017-06-22) * paragraph [0080]; figure 4 * -----	6,10	
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 28 June 2023	Examiner Collado Garrido, Ana
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	

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ON EUROPEAN PATENT APPLICATION NO.

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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28-06-2023

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