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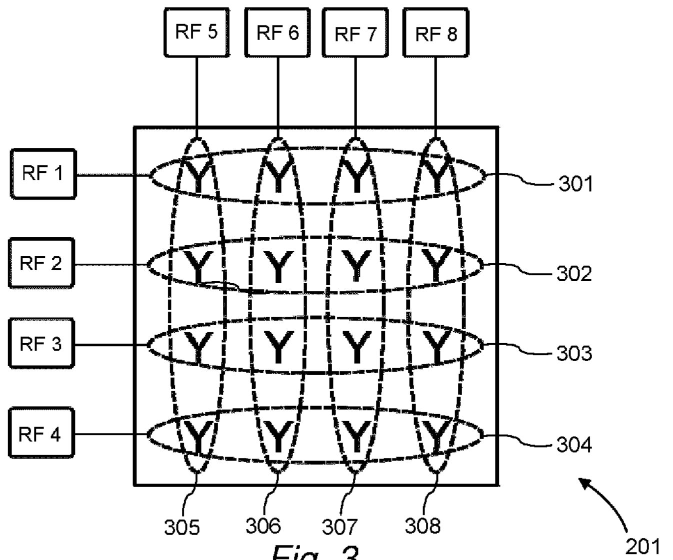

Fig. 3

(57) Abstract: An antenna array (105) for a wireless communication device (1020 is disclosed. The antenna array (105) comprises a two-dimensional array (203) of radiators configured as a plurality of sub-arrays (301 – 308) of radiators, each sub-array being configured for coupling to a radio chain (206). The two-dimensional array of radiators includes one or more radiators (203a) that are common radiators of a first and a second sub-array (301, 305) of radiators, the one or more common radiators (230a) being common to the first and the second sub-array (301, 305). The common radiators may thus be independently controlled by a radio chain of each of first sub-array and the second sub-array. This advantageously enables a relatively greater number of sub-arrays, each sub-array comprising a given number of radiators, to be formed from a given number of radiators, which may advantageously allow for an increased transmit/receive data rate and/or improved control of the radiation profile of a transmit array.

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ANTENNA ARRAY

Field of the Disclosure

The present disclosure relates to an antenna array for a wireless communication device and a method for operating an antenna array for a wireless communication device, a base station for a wireless communication network comprising an antenna array, and a wireless communication network comprising a base station.

Background of the Disclosure

Many standards for wireless communications in licensed frequency bands, such as Long-Term Evolution (LTE) use multi-antenna techniques, also known as multiple-input multiple-output (MIMO). A base station in such a system is equipped with multiple antennas, which increases the spatial resolution of the radiation profile of the base station and provides an energy-efficient way to serve multiple user equipments in the same time-frequency resource. To maximise the spatial resolution of the radiation profile of the base station it can be desirable to increase the number of antennas in the base station. However, practical constraints may limit the number of radiating elements with which the base station can be equipped.

Summary of the Disclosure

An object of the present disclosure is to provide an antenna array suitable for wireless radio-frequency (RF) communications. The antenna array should be compact and suitable for generating a variety of radiation patterns.

The foregoing and other objects are achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the Figures.

In general terms, the antenna array described in detail below enables a relatively greater number of sub-arrays to be formed from a given number of radiators. This, in turn, allows for increased spatial resolution of the radiation profile of the base station despite a limitation on the number of radiators.

A first aspect of the present disclosure provides an antenna array (105) for a wireless communication device (102), comprising: a two-dimensional array (203) of radiators configured as a plurality of sub-arrays (301 – 308) of radiators, each sub-array being configured for coupling to a respective radio chain (206), wherein the two-dimensional array (203) includes one or more radiators (203a) that are common radiators of a first and second sub-array (301, 305) of radiators.

Each sub-array of radiators is configured for coupling to a respective radio chain, e.g. inputs of radiators of each sub-array are electrically coupled to be suitable for coupling to a common radio chain. One or more of the radiators are configured to be common to a least a first and second of the sub-arrays, i.e. the common radiators are electrically coupled with radiators of each of those sub-arrays such that the common radiators may be coupled to both to a radio chain feeding the first sub-array and a radio chain feeding the second sub-array. The common radiators may thus be independently controlled by a radio chain of each of the first sub-array and the second sub-array. Each of the one or more common radiators could, for example, comprise a single radiating element, that is fed by different radio chains, for example, by a first radio chain of the first sub-array and by a second radio chain of the second sub-array. Alternatively, each of the common radiators could comprise plural co-located radiating elements, for example, each radiator could comprise first and second co-located radiating elements, each of the co-located radiating elements forming a part of a respective sub-array.

In other words, at least the first and second sub-arrays, i.e. first and second antennas, may utilise the same, one or more, radiator(s) in their respective sub-arrays. In this configuration, for a given number of radiators, which may be practically constrained by aperture size for a given radiator spacing, and a given number of radiators per sub-array, which may be similarly constrained by a desire to maintain given gain, data-rate, spatial diversity and/or directivity characteristics for each sub-array, the invention facilitates forming of a relatively greater number of sub-arrays/antennas than if each of the radiators were utilised by only a single sub-array. For an antenna array formed by the sub-arrays, the greater number of sub-arrays may advantageously enable an increased transmit/receive data-rate and/or increased spatial resolution of the radiation profile of a transmit array.

In this specification, the term ‘sub-array’ is used to define a subset of an array of radiators, i.e. more than one radiator of an array but fewer than the entire array of radiators. The term ‘radio chain’ is used to mean circuitry for transmitting and/or receiving a radio frequency signal using the radiators, e.g. a transmitter, or a receiver, or a transceiver device. A radio chain may further comprise circuitry for processing the radio-frequency signal.

In an implementation, the one or more common radiators are multi-mode radiators. In other words, the radiator may be a single radiating element comprising multiple radio-frequency input ports which excite different characteristic modes. This may advantageously allow for the radiator to be utilised by sub-arrays emitting at mutually different radio frequencies. Further, a multi-mode radiator may advantageously allow for relatively simple coupling of the radiator to radio chains of multiple sub-arrays, by coupling of each radio chain to a respective one of the multiple input ports.

In an implementation, each of the one or more common radiators comprises a power divider having an output port coupled to an input of the common radiator and first and second input ports for coupling to first and second radio chains respectively. The power divider may thus advantageously allow convenient combining of input signals from multiple radio chains into a single input port of a radiator.

In an implementation, the power divider is a hybrid coupler. A hybrid coupler may advantageously maintain high isolation between the input ports.

In an implementation, the first sub-array and the second sub-array are non-parallel. Radiation patterns generated by parallel sub-arrays, i.e. by sub-arrays in which axes of the sub-arrays extending in an average direction of the radiators of each sub-array are parallel, are disadvantageously susceptible to high correlation. In comparison, radiation patterns produced by non-parallel, for example, mutually perpendicular, sub-arrays are most spatially different, i.e. best de-correlated, which may advantageously reduce cross-talking between different channels and thereby improve transmission/reception of different data streams.

In an implementation, the first sub-array and the second sub-array are mutually perpendicular. In other words, the first and second sub-arrays may be oriented such that respective axes of the first and second sub-arrays, extending in an average direction of the radiators of the first and second sub-arrays respectively, are mutually perpendicular. For example, the two-dimensional array may comprise a square array of radiators arranged in linear rows and columns, the first sub-array may comprise radiators arranged along a row of the array, and the second sub-array may comprise radiators arranged along a column of the array. In this configuration, the radiation patterns produced by the sub-arrays may be most spatially different, which advantageously allows for a high degree of de-correlation between the respective emissions of the sub-arrays.

In an implementation, one or both of the first sub-array and the second sub-array is diagonally-oriented. In other words, the radiators of a sub-array may be arranged diagonally across the array. For a rectangular array, the diagonal dimension is the longest dimension, such that the radiators will be spaced over a greatest distance in the diagonal dimension. The increased length dimension of diagonally-oriented sub-arrays may advantageously enable a radiation pattern to be formed by the sub-array having a higher directivity, which may increase the spatial resolution of the antenna array. The diagonally-oriented sub-array(s) may extend a full diagonal dimension of the array of radiators, i.e. the sub-array(s) may comprise radiators located at diametrically opposite corners of the array, which may advantageously maximise the length of the sub-array. i.e. the distance between radiators of the sub-array.

In an implementation, the plurality of sub-arrays comprise a plurality of column-oriented sub-arrays and a plurality of row-oriented sub-arrays, each column-oriented sub-array comprising radiators arranged along a column of the two-dimensional array, and each row-oriented sub-array comprising radiators arranged along a row of the two-dimensional array, wherein for each column-oriented sub-array and each row-oriented sub-array the two-dimensional array comprises one or more radiators that are common to the respective column-oriented sub-array and the respective row-oriented sub-array. In other words, each column of radiators may be configured as a sub-array and each row of radiators may be configured as a further sub-array. This arrangement may most efficiently share radiators in the array between different sub-arrays, thereby resulting in a maximum number of sub-arrays for a given number of radiators in the two-dimensional array. This may thus advantageously further improve the transmit/receive data rate of the two-dimensional array and/or the degree of control of the radiation profile of a transmit two-dimensional array.

In an implementation, the antenna array comprises a further two-dimensional array of radiators, each radiator of the further two-dimensional array being co-located with a radiator of the two-dimensional array, and each radiator of the further two-dimensional array having a polarisation different to a polarisation of the co-located radiator of the two-dimensional array.

In other words, the antenna array may comprise dual-polarised radiators formed by two arrays of oppositely-polarised radiators. For example, the radiators of the two-dimensional array may be horizontally polarised, and the radiators of the further two-dimensional array may be vertically polarised. Signals with orthogonal polarisation are less susceptible to mutual interference in the near-field of the radiators. Co-located, oppositely polarised, radiators of a transmit array may be deployed for transmitting a same data set to similarly oppositely polarised radiators of a receive array. This may advantageously increase the data robustness of the transmission, as each receive radiator may receive a copy of the data set via its correspondingly polarised signal. Furthermore, the greater number of sub-arrays may provide increased spatial resolution.

In an implementation, the antenna array comprises a plurality of radio chains, each radio chain being coupled to a sub-array of the radiators. For example, the antenna array may comprise a first radio chain coupled to radiators of the first sub-array, and a second radio chain coupled to radiators of the second sub-array. The sub-arrays of radiators may thus be independently controlled by their respective radio chains, to thereby function as independent antennas.

In an implementation, each of the one or more radiators that are common radiators of a first and second sub-array of radiators comprises a first radiating element and a second radiating element, the first radiating element forms part of the first sub-array of radiators and the second radiating element forms part of the second sub-array of radiators. In this arrangement, an increased number of radiating elements may be formed by a given number of radiators, thereby advantageously allowing forming of an increased number of sub-arrays of radiators for the given number of radiators in an array. For example, in this implementation each radiator of the two-dimensional array could comprise a first radiating element and a second radiating element, the first radiating element of each radiator could form part of a sub-array, such as the first sub-array, and the second radiating element of each radiator could form a part of a further sub-array, such as the second sub-array.

A second aspect of the present disclosure provides a base station for a wireless communication network, the base station comprising an antenna array as defined in any one of the preceding statements for wirelessly communicating with remote user equipment. The relatively greater number of sub-arrays facilitated by the disclosure for a given number of radiators may advantageously increase uplink/downlink capacity between the base station and remote user equipment, thereby facilitating serving of an increased number of remote user equipment devices by the base station, and furthermore may provide increase spatial resolution of the radiation profile.

A third aspect of the present disclosure provides a method of operating an antenna array for a wireless communication device, the antenna array comprising a two-dimensional array of radiators, the two-dimensional array comprising one or more radiators that are common radiators of a first and second sub-array of radiators, the one or more common radiators being common to the first and the second sub-array, the method comprising: generating a first radio-frequency emission using a first radio chain coupled to the first sub-array of the radiators, and generating a second radio-frequency emission using a second radio chain coupled to the second sub-array of the radiators.

In other words, the method comprises generating first and second radio-frequency emissions using first and second antennas respectively, the first antenna comprising the first radio chain and the first sub-array of radiators, and the second antenna comprising the second radio chain and the second sub-array of radiators, where the first and second sub-arrays of the first and second antennas respectively utilise one or more common radiators for the respective radio emissions.

By this method, for a given number of radiators in the two-dimensional array, which number may be practically constrained by aperture size for a given radiator spacing, and for a given number of radiators per sub-array, which number may be similarly constrained by a desire to maintain given gain, data-rate, spatial diversity and/or directivity characteristics for each sub-array, the invention facilitates the deployment of a relatively greater number of sub-arrays/antennas than if each of the radiators were utilised by only a single sub-array. For an antenna array formed by the sub-arrays, the greater number of sub-arrays achieved by the method may advantageously enable the an increased transmit/receive data-rate and/or increased spatial resolution of the radiation profile of a transmit array.

In an implementation, the method comprises generating the first radio-frequency emission and the second radio-frequency emission simultaneously. Generating the two radio-frequency emissions simultaneously may advantageously reduce the time required for emission of the two signals, thereby advantageously increasing the uplink/downlink capacity of the antenna array over a single time-frequency resource.

In an implementation, the method may comprise using the first radio-frequency emission as a carrier for a first data-set, and the second radio-frequency emission as a carrier for a second, different, data-set. Using the sub-arrays to transmit different data sets simultaneously may advantageously increase the achievable data rate of transmission. Because the emissions are generated at different radio frequencies, correlation between the signals may advantageously be reduced.

In an implementation, the method may comprise coupling the first radio chain and the second radio chain to the one or more radiators common to the first sub-array and the second sub-array by a power divider having an output port coupled to the radiator and first and second input ports coupled to the first and second radio chains respectively. The power divider may thus advantageously allow convenient combining of input signals from multiple radio chains into a single input port of a radiator. For example, the power divider could be a hybrid coupler. A hybrid coupler may advantageously maintain high isolation between the input ports.

These and other aspects of the invention will be apparent from the embodiment(s) described below.

Brief Description of the Drawings

In order that the present invention may be more readily understood, embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows schematically an example of wireless communication network embodying an aspect of the invention comprising a base station in wireless communication with remote user equipment;

Figure 2 shows schematically an antenna array of the base station of the wireless network comprising a two-dimensional array of radiators coupled to a plurality of radio chains;

Figure 3 shows schematically a first configuration of the two-dimensional array of radiators of the antenna array;

Figure 4 shows schematically a second configuration of the two-dimensional array of radiators of the antenna array;

Figure 5 shows a first coupling of radio chains to a radiator of the two-dimensional array;

Figure 6 shows a second coupling of radio chains to the radiator of the two-dimensional array;

Figure 7 shows schematically a method for operating the base station of the wireless network to transmit signals to, and receive signals from, the remote user equipment;

Figure 8 shows schematically an exemplary alternative antenna array of the base station of the wireless network comprising an array of dual-polarised crossed-dipole radiator structures forming first and second two-dimensional arrays of radiators coupled to a plurality of radio chains; and

Figure 9 shows schematically a configuration of the first and second two-dimensional arrays of radiators of the example alternative antenna array.

Detailed Description of the Disclosure

A wireless communication network 101 embodying an aspect of an invention of the present disclosure is illustrated schematically in the Figures.

Referring firstly to Figure 1, the wireless communication network 101 comprises a base station, indicated generally at 102, in wireless communication with remote user equipment 103. Base station 102 comprises a mast 104 supporting an antenna array 105 at a height above ground level. Remote user equipment 103 comprises a hand-held cellular telephone handset 106. Handset 106 comprises one or more internal antennas, each of the one or more antennas comprising a radiator and radio chain pair. The base station 102 and telephone handset 103 are configured to communicate via radio-frequency transmission, for example, via radio communication operating according to the Long-Term Evolution (LTE) telecommunications standard.

Referring secondly in particular to Figure 2, the antenna array 105 comprises a radiator assembly, indicated generally at 201, and RF circuitry, indicated generally at 202.

Radiator assembly 201 comprises a plurality of discrete radiators 203, arranged as an N-by-M rectangular array, N and M being integer numbers greater than or equal to two, i.e. $N \geq 2$ and $M \geq 2$. In the example, there are sixteen radiators, including radiators 203a to 203i, arranged as a four-by-four square array, on a planar base 204. In the example each of the radiators 203 comprises a singularly-polarised, specifically a horizontally-polarised, dipole radiating element.

RF circuitry 202 comprises a baseband processor module 205, a plurality of radio chains 206 (in the example eight radio chains RF 1 to RF 8), and a coupler module 207. An input of baseband processor module 205 is coupled to a baseband signal source. Outputs of the baseband processor module 205 are coupled to a respective one of the radio chains 206. The baseband processor module 205 is thus operable to receive and process a baseband signal, and output representations of the processed RF signal to each of the radio chains 206. In the example, each radio chain 206, comprises a radio transceiver and an RF frequency amplifier coupled in series with the radio transceiver. An input of each radio chain 206 is coupled to an output of the processor module 205.

An output of each radio chain 206 is coupled to an input of coupler module 207. Each radio chain 206 is thus operable to receive and controllably amplify the baseband signal representation, generate a radio-frequency alternating current carrying a baseband signal component, and output the amplified radio-frequency alternating current to an input of the coupler module 207. The coupler module 207 comprises manually configurable circuits for coupling the radio chains 206 to inputs of the radiators 203 of the radiator assembly 201. Inputs of the coupler module 207 are coupled to outputs of the radio chains 206. Outputs of the coupler module 207 are coupled to inputs of the radiators 203 of the radiator assembly 201. In the example, the coupler module 207 has sixteen outputs, each of the sixteen outputs being coupled to a respective one of the radiators 203, such that the radiators 203 are individually addressed by the coupler module 207. The coupler module 207 is thus operable to couple the radio chains 206 to the radiators 203 to thereby apply radio frequency alternating currents generated by the radio chains 206 to the radiators 203.

Referring next in particular to Figures 3 and 4, the coupler module 207 is configurable to couple each of the radio chains 206 to sub-arrays, i.e. groups, of the radiators 203 of the radiator assembly 201, by coupling each input of the coupler module 207 to four outputs of the coupler module 207.

In a first configuration, illustrated in Figure 3, each of the radio chains 206 is coupled to a sub-array of four of the radiators 203, such that the radiator assembly 201 is configured to form eight independently controlled sub-arrays 301 to 308. Sub-arrays 301 to 304, coupled to radio chains RF 1 to RF 4 respectively, are formed by radiators arranged in a respective row of the array. For example, sub-array 301, coupled to radio chain RF 1, is formed by radiators 203a, 203b, 203c and 203d. Sub-arrays 305 to 308, coupled to radio chains RF 5 to RF 8 respectively, are formed by radiators arranged in a respective column of the array. For example, sub-array 305, coupled to radio chain RF 5, is formed by radiators 203a, 203e, 203f and 203g.

In the second configuration, illustrated in Figure 4, each of the radio chains 206 is again coupled to a sub-array of four of the radiators 203, such that again the radiator assembly 201 forms eight independently controlled sub-arrays 401 to 408. In this second configuration each of the sub-arrays comprises four radiators 203 arranged in a two-by-two square array. For example, sub-array 401, coupled to radio chain RF 1, is formed by radiators 203b, 203c, 203h and 203i.

It will be observed that, in the exemplary configurations illustrated in Figures 3 and 4, at least a portion of radiators 203 of the radiator assembly 201 are shared between, i.e. utilised separately by, different sub-arrays. In the configuration of Figure 3, each radiator 203 of the assembly 201 is shared between a row-oriented sub-array and a column-oriented sub-array, for example, radiator 203a is shared between horizontally oriented sub-array 301 and vertically oriented sub-array 305. Similarly, in Figure 4, several of the radiators are shared between multiple sub-arrays. For example, radiator 203h is shared by three different sub-arrays, namely, sub-array 401, sub-array 402, and sub-array 405. Configuring the radiators 203 to form a part of more than one sub-array simultaneously advantageously allows for a relatively greater number of four-radiator sub-arrays to be formed from the radiator assembly 201 than is possible by a conventional configuration in which each radiator is accessible by only a single radio chain.

In this respect, the disclosure may have particular utility in a wireless communication system, such as a communication system operating in accordance with the LTE standard, operating using a multi-antenna technique, such as multiple-input multiple output (MIMO) system, and even a Massive MIMO (M-MIMO) system.

In particular where the radiating structure forms a part of a M-MIMO system, the number of sub-arrays required to achieve a desirably high degree of control of the radiation profile of the array may be especially great. However, the maximum size of the radiating structure, and so the available area for the radiator array, is often constrained, for example, due to restricted ground area for installation of the radiating structure, as may be experienced commonly where the radiating structure is installed in a densely populated city location. Further, it is typically impermissible, or at least undesirable, to attempt to populate the available array area with a greater number of radiators by reducing the spacing between radiators, because densifying the radiators may result in radiation patterns from the sub-array undesirably become highly correlated. These factors may thus place an upper limit on the number of radiators which may be disposed in an array. Furthermore, it is typically undesirable to form additional sub-arrays simply by reducing the number of radiators in each sub-array, as reducing the number of radiators in a sub-array may reduce the gain, directivity, and/or spatial diversity characteristics of the radiation of each sub-array. These factors may thus place a lower limit on the number of radiators which may form a sub-array. The disclosure however overcomes these practical limitations, by configuring radiators of the array to be shared between one or more sub-arrays.

Thus, by the disclosure, for a given number of radiators in an array, and a given number of radiators per sub-array, a relatively greater number of sub-arrays may be formed with radiators of the array. The relatively greater number of sub-arrays may advantageously allow for improved control of the radiation profile of the array of radiators, thereby improving the ability of the antenna array to form a spatially selective beam for transmission of (and reception of) RF signals to (and from) remote user equipment, e.g. for improved beamforming performance, thereby allowing for increased cell throughput.

Referring next to Figure 5, in the example each of the radiators 203 of the array, such as radiator 203a, is a multi-mode radiator comprising multiple independent input ports for coupling to respective output ports of the coupler module 207. For the configuration described with reference to Figure 3, in which each radiator 203 of the radiator assembly 201, for example, radiator 203a is coupled to first and second radio chains, for example, radio chains RF 1 and RF5, a first input of the multi-mode radiator is coupled to a first output port of the coupler module 207, and a second input port of the multi-mode radiator is coupled to a second output port of the coupler module 207. The multi-mode radiator may thereby be excited by radio-frequency alternating current generated by each of the coupled radio chains, for example, radio chains RF 1, RF 5.

Referring next to Figure 6, in an alternative embodiment, radiators 203 of the array, such as radiator 203a, may comprise a single input port, and may comprise a signal combining device, such as hybrid coupler 601, coupled to the input of the radiator 203. The signal combining device may receive signals from two or more radio chains, for example, from radio chains RF 1 and RF 5, and combine the signals for application to the radiator 203. The signal combining device, for example, the hybrid coupler, could be integrated into the coupler module 207, such that outputs of the coupler module 207 are coupled in series with outputs of the hybrid couplers.

Referring, to Figure 7, an exemplary method for operating the antenna array 105 to communicate wirelessly with remote user equipment, such as handset 106, is depicted schematically.

At step 701, the RF circuitry 202 is coupled to the radiators 203 of the radiator assembly 201. At step 702, an input baseband signal is received by the baseband processor module 205. At step 703 the baseband processor module 205 performs signal processing operations on the baseband signal, for example, power amplification operations, under the control of an external computing device (not shown in the Figures). At step 704, the processed baseband signal is fed to the radio chains, which produce respective radio-frequency alternating currents. At step 705, the hybrid coupler 207 is manually configured to couple the radio chains 206 to radiators 203 of the radiator assembly 201 to form the desired number and shape of sub-arrays. For example, for the configuration described with reference to Figure 3, the hybrid coupler 207 is configured to couple an output of radio chain RF 1 to respective inputs of radiators 203a, 203b, 203c and 203d, and an output of radio chain RF 5 to respective inputs of radiators 203a, 203e, 203f and 203g. At step 706, the radio-frequency alternating current signals generated by the radio chains 206 are applied to the radiators 203 to excite respective radio emissions in a frequency band tuned with receive circuitry of remote handset 106. Finally, at step 707, the RF circuitry 202 is set to listen for a radio signal generated by the remote handset 106.

Referring next to Figures 8 and 9, in an alternative embodiment of the invention the radiator assembly 201' comprises an array of dual-polarised radiator structures 203', for example, radiator structures 203a' to 203g', first RF circuitry 202' for supplying radio-frequency alternating current to a first singularly polarised radiator of each radiator structure 203', and second RF circuitry 801 for supplying radio-frequency alternating current to a second singularly polarised radiator of each radiator structure 203'.

In the illustrated alternative embodiment, a first two-dimensional array of radiators and a further two-dimensional array of radiators are implemented as an array of crossed-dipole radiator structures 203'. Each dipole element of each crossed-dipole radiator structure functions as an independently controllable radiator coupled to one or more radio chains of the RF circuitry 202' or 801. The first and second RF circuitry 202', 801 are substantially alike, and indeed identical to RF circuitry 202 described previously with reference to Figures 1 to 7, and like reference numerals will be used to denote like features.

Each of the dual-polarised radiator structures 203' comprises a crossed-dipole structure formed of two co-located independent dipole radiating elements arranged mutually orthogonally. Referring in particular to Figure 9, a first dipole radiating element of each crossed-dipole radiating structure 203' is coupled to first RF circuitry 202', and thus forms a first four-by-four two-dimensional array of radiators. A second dipole radiating element of each crossed dipole radiating structure 203' is coupled to second RF circuitry 801, and thus forms a further four-by-four two-dimensional array of radiators. A first radiating element of each radiator structure 203' is coupled to a first one of the radio chains, to thereby form a part of a first sub-array of radiators. A second radiating element of each radiator structure 203' is coupled to a second one of the radio chains, to thereby form a part of a second sub-array of radiators. For example, radio chain RF 1 of first RF circuitry 202' is coupled to a first dipole radiator element of radiator structures 203a', 203b', 203c' and 203d', thereby forming a first sub-array of radiators, whilst radio chain RF 9 of second RF circuitry 801 is coupled to a second, relatively cross-polarised, dipole radiating element of radiator structures 203a', 203b', 203c' and 203d', thereby forming a second sub-array of radiators.

Each of the dipole radiating elements of each of the crossed-dipole radiator structures 203' is similarly shared between two sub-arrays for excitation by radio chains associated with the sub-arrays. For example, a first dipole radiating element of radiator structures 203a', 203b', 203c' and 203d' is coupled to radio chain RF 1 and a respective one of radio chains RF 5, RF 6, RF 7 and RF 8, and a second dipole radiating element of the radiator structures 203a', 203b', 203c' and 203d' is coupled to radio chain RF 9 and a respective one of radio chains RF 13, RF 14, RF 15 and RF 16.

Thus, in the embodiment, the array of sixteen crossed-dipole radiator structures 203' form sixteen independently controllable sub-arrays of radiators, 901 to 916, each sub-array comprising four singularly-polarised dipole radiators.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims._In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality.

Claims

1. An antenna array (105) for a wireless communication device (102), comprising:

a two-dimensional array (203) of radiators configured as a plurality of sub-arrays (301 – 308) of radiators, each sub-array being configured for coupling to a respective radio chain (206), wherein

the two-dimensional array (203) includes one or more radiators (203a) that are common radiators of a first and second sub-array (301, 305) of radiators.

2. An antenna array as claimed in claim 1, wherein the one or more common radiator are multi-mode radiators.

3. An antenna array as claimed in claim 1, wherein each of the one or more common radiators comprises a power divider (601) having an output port coupled to the radiator and first and second input ports for coupling to first and second radio chains respectively.

4. An antenna array as claimed in claim 3, wherein the power divider is a hybrid coupler.

5. An antenna array as claimed in any one of the preceding claims, wherein the first sub-array (301) and the second sub-array (305) are non-parallel.

6. An antenna array as claimed in any one of the preceding claims, wherein the first sub-array and the second sub-array are mutually perpendicular.

7. An antenna array as claimed in any one of the preceding claims, wherein one or both of the first sub-array and the second sub-array are diagonally-oriented.

8. An antenna array as claimed in any one of claims 1 to 6, the plurality of sub-arrays comprising a plurality of column-oriented sub-arrays and a plurality of row-oriented sub-arrays, each column-oriented sub-array comprising radiators arranged along a column of the two-dimensional array, and each row-oriented sub-array comprising radiators arranged along a row of the two-dimensional array, wherein for each column-oriented sub-array and each row-oriented sub-array the two-dimensional array comprises one or more radiators that are common to the respective column-oriented sub-array and the respective row-oriented sub-array.

9. An antenna array as claimed in any one of claims 1 to 8, comprising a further two-dimensional array of radiators, each radiator of the further two-dimensional array being co-located with a radiator of the two-dimensional array, and each radiator of the further two-dimensional array having a polarisation different to a polarisation of the co-located radiator of the two-dimensional array.

10. An antenna array as claimed in any one of the preceding claims, comprising a plurality of radio chains, each radio chain being coupled to a sub-array of the radiators.

11. An antenna array as claimed in any one of the preceding claims, wherein each of the one or more radiators (203a) that are common radiators of a first and second sub-array (301, 305) of radiators comprises a first radiating element and a second radiating element, the first radiating element forms part of the first sub-array of radiators (301) and the second radiating element forms part of the second sub-array of radiators (302).

12. A base station for a wireless communication network, the base station comprising an antenna array as claimed in any one of the preceding claims for wirelessly communicating with remote user equipment.

13. A method of operating an antenna array for a wireless communication device, the antenna array comprising a two-dimensional array (203) of radiators, the two-dimensional array (203) including one or more radiators (203a) that are common radiators of a first and a second sub-array (301, 305) of radiators, the method comprising:

generating a first radio-frequency emission using a first radio chain coupled to the first sub-array of the radiators, and

generating a second radio-frequency emission using a second radio chain coupled to the second sub-array of the radiators.

14. A method as claimed in claim 13, comprising generating the first radio-frequency emission and the second radio-frequency emission simultaneously.

15. A method as claimed in claim 13 or claim 14, wherein the first radio-frequency emission acts as a carrier for a first data-set, and the second radio-frequency emission acts as a carrier for a second, different, data-set.

16. A method as claimed in any one of claims 13 to 15, comprising coupling the first radio chain and the second radio chain to each of the one or more radiators common to the first sub-array and the second sub-array by a power divider (601) having an output port coupled to the respective radiator and first and second input ports coupled to the first and second radio chains respectively.

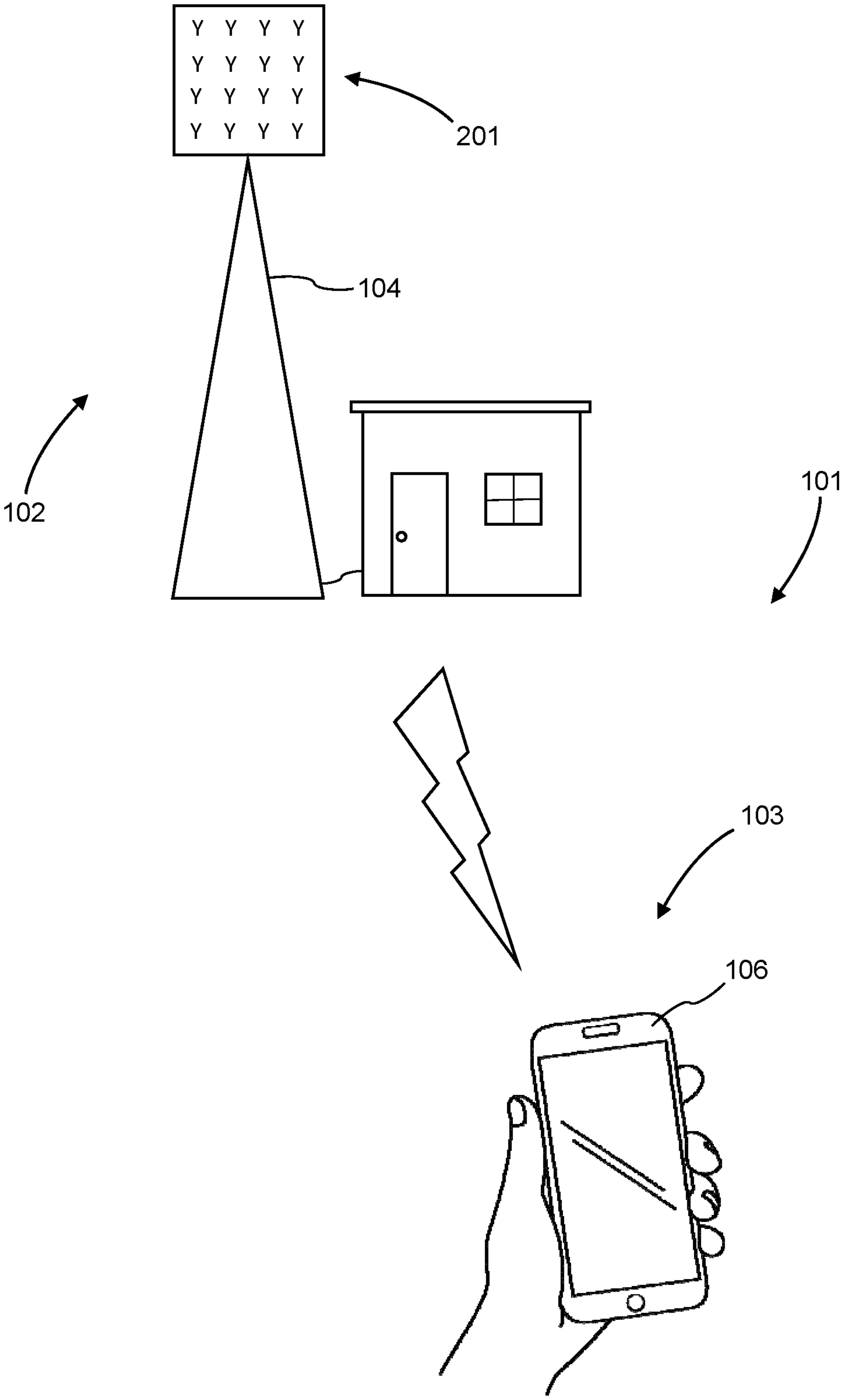

Fig. 1

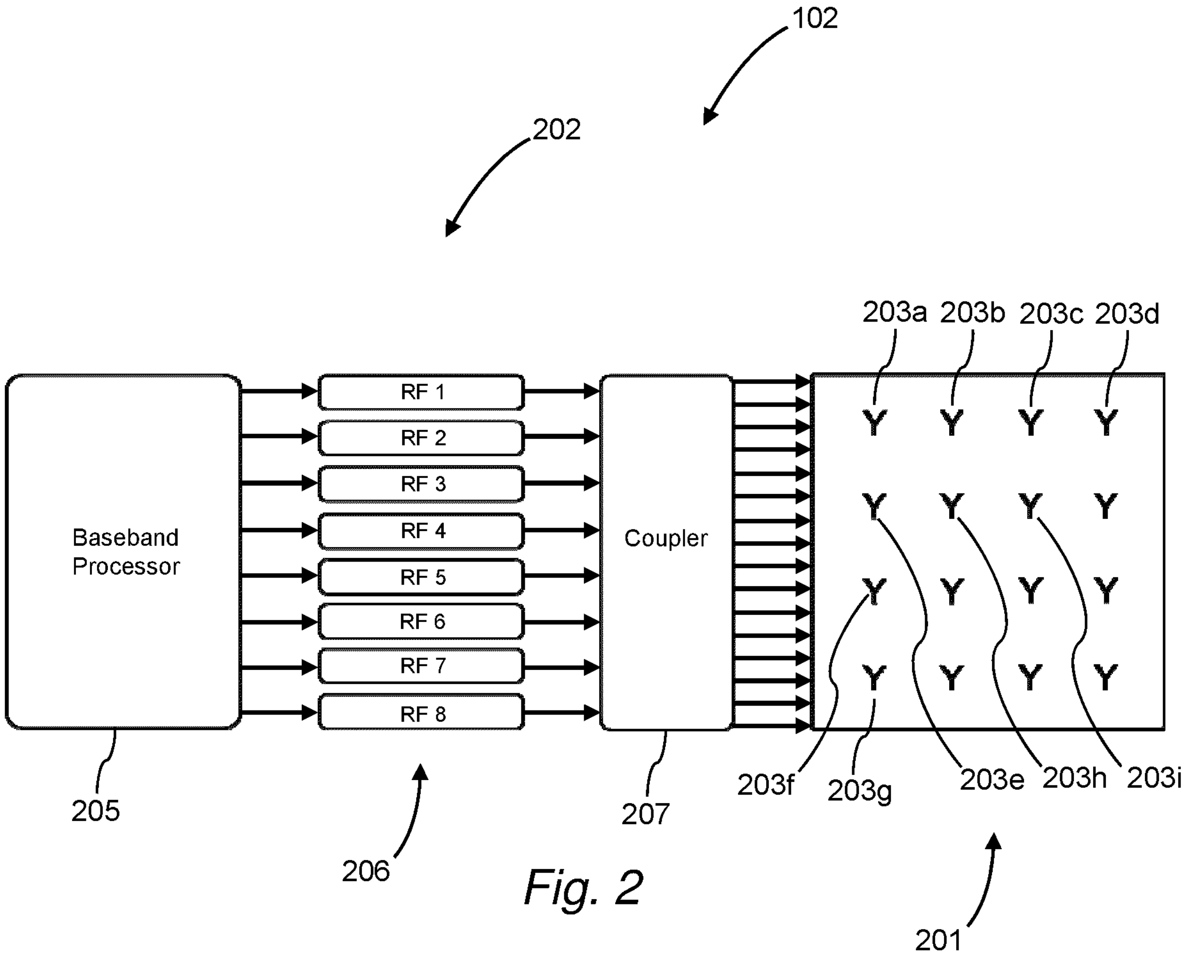
102
202
203a
203b
203c
203d
Baseband Processor
RF 1
RF 2
RF 3
RF 4
RF 5
RF 6
RF 7
RF 8
Coupler
205
206
207
203f
203g
203e
203h
203i
201

Fig. 2

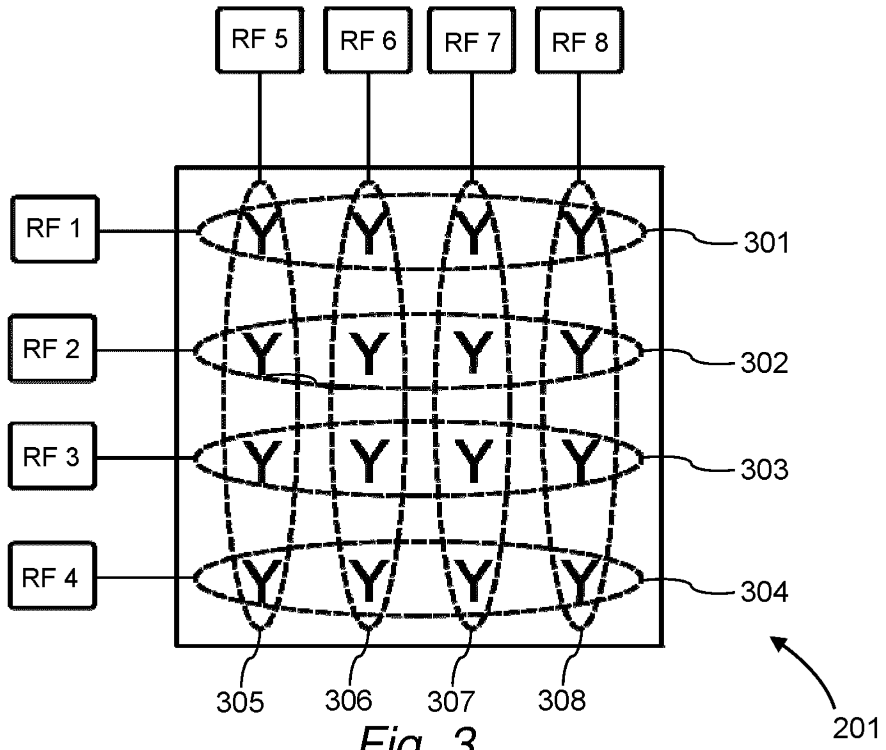
RF 5
RF 6
RF 7
RF 8
RF 1
RF 2
RF 3
RF 4
301
302
303
304
305
306
307
308
201

Fig. 3

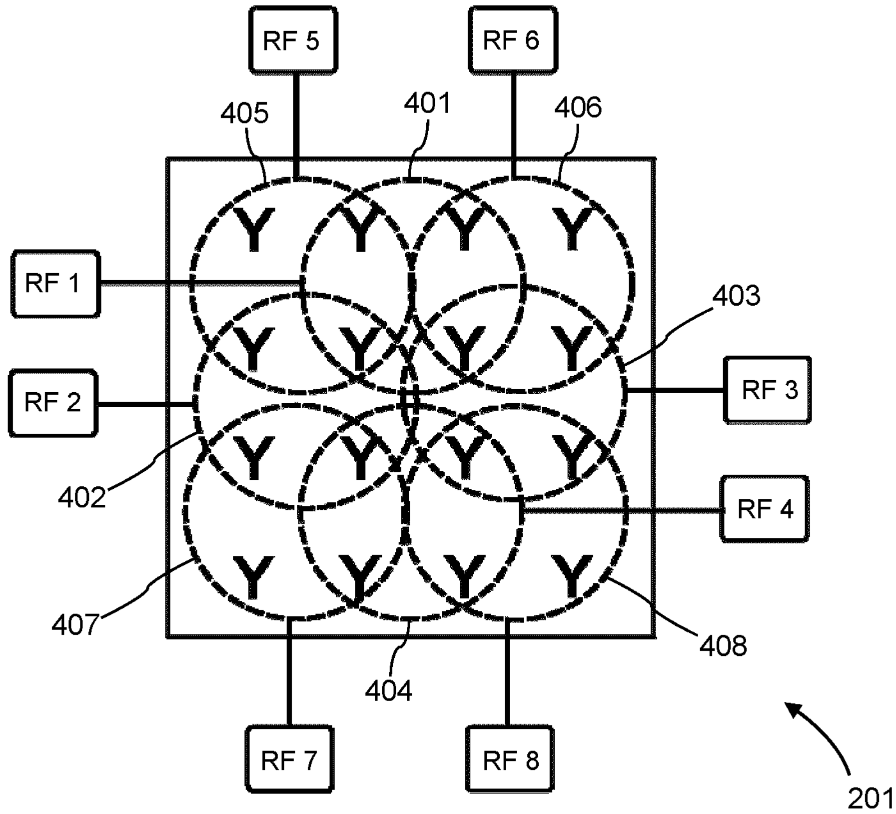
RF 5
RF 6
405
401
406
RF 1
403
RF 2
RF 3
402
RF 4
407
408
404
RF 7
RF 8
201

Fig. 4

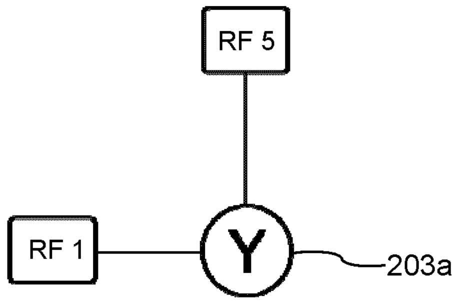

Fig. 5

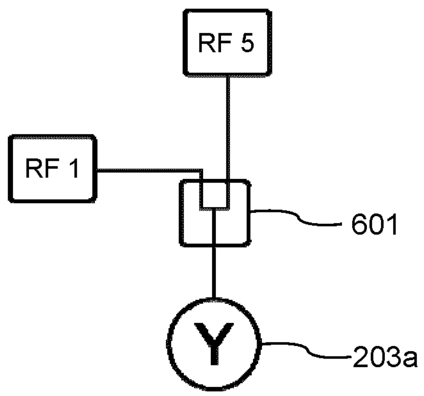

Fig. 6

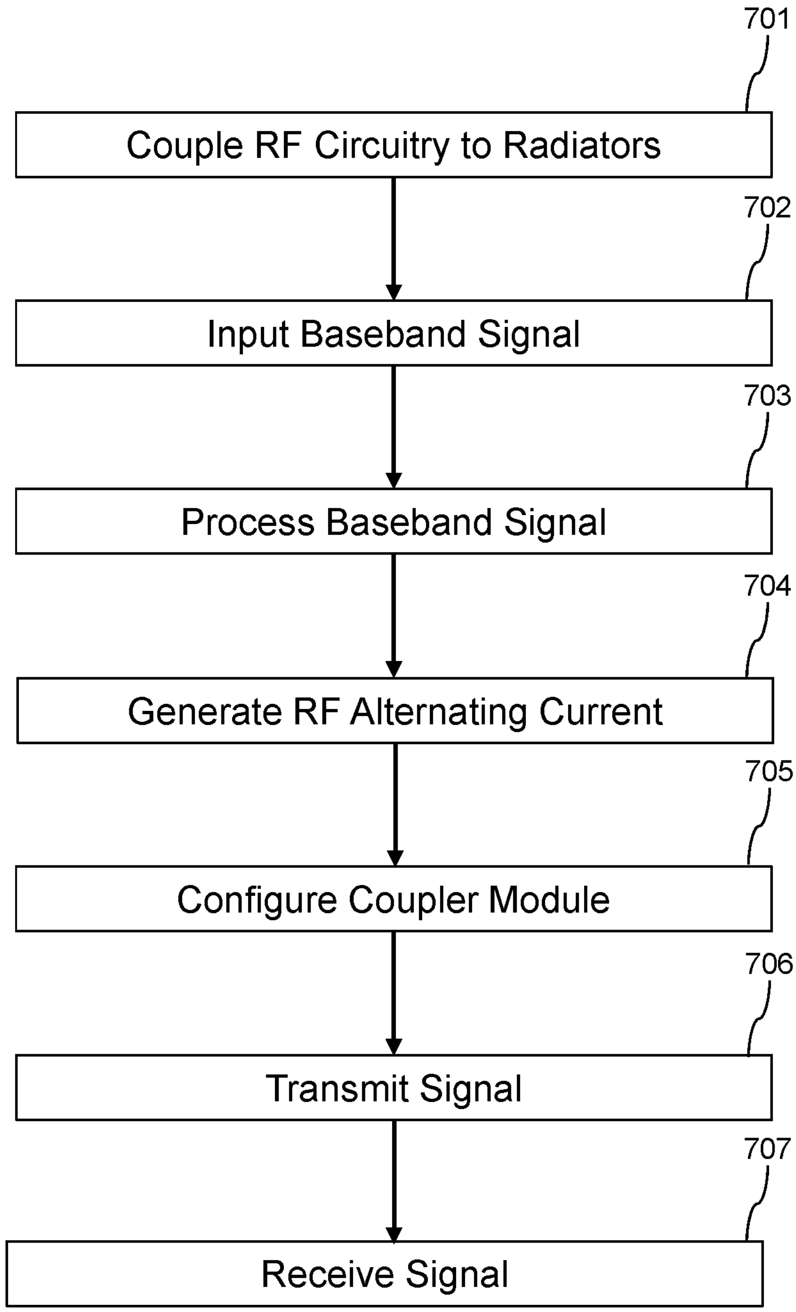
701
Couple RF Circuitry to Radiators
702
Input Baseband Signal
703
Process Baseband Signal
704
Generate RF Alternating Current
705
Configure Coupler Module
706
Transmit Signal
707
Receive Signal

Fig. 7

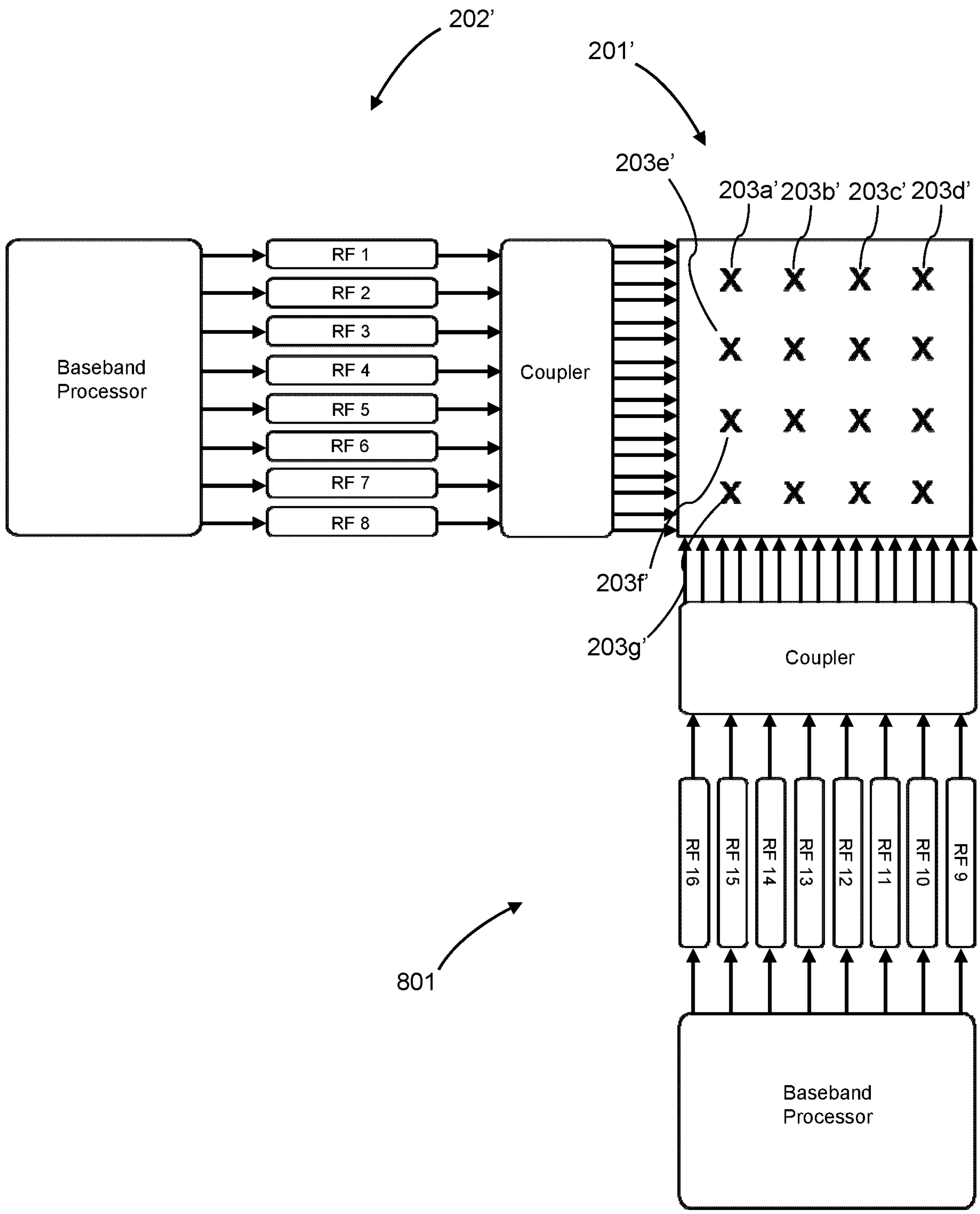
202'
201'
203e'
203a'
203b'
203c'
203d'
Baseband Processor
RF 1
RF 2
RF 3
RF 4
RF 5
RF 6
RF 7
RF 8
Coupler
203f'
203g'
Coupler
RF 16
RF 15
RF 14
RF 13
RF 12
RF 11
RF 10
RF 9
801
Baseband Processor

Fig. 8

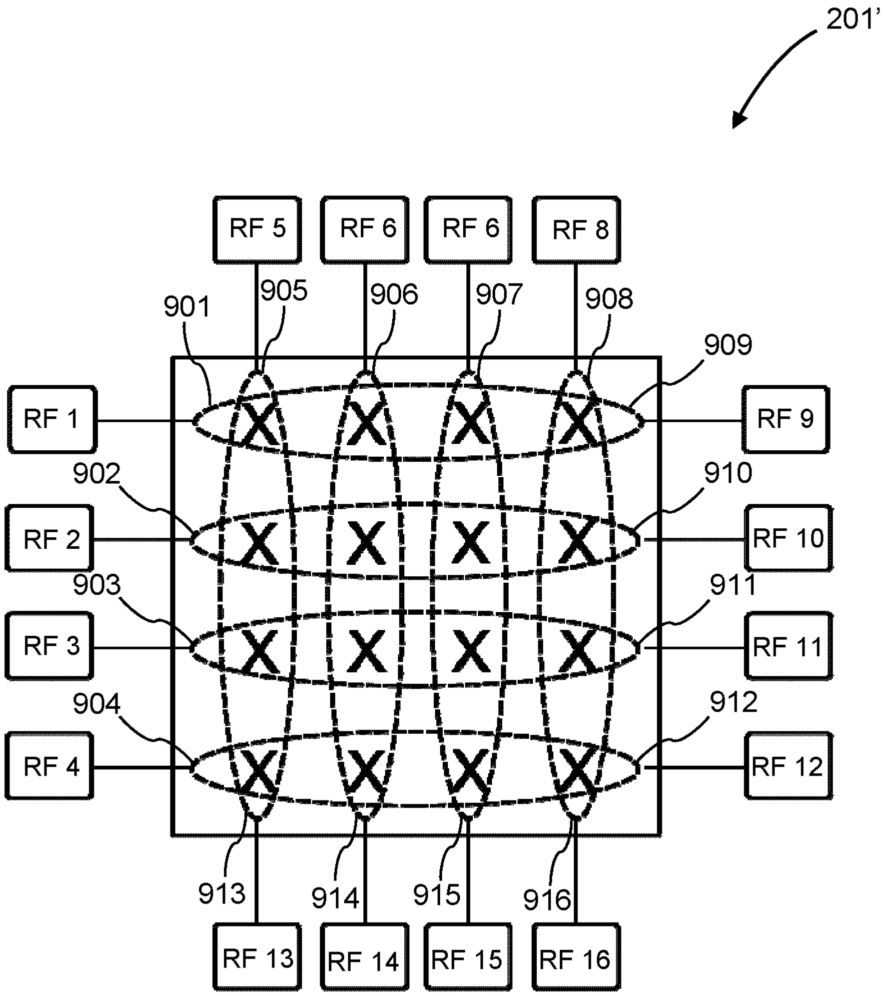
201'
RF 5
RF 6
RF 6
RF 8
901
905
906
907
908
909
RF 1
RF 9
902
910
RF 2
RF 10
903
911
RF 3
RF 11
904
912
RF 4
RF 12
913
914
915
916
RF 13
RF 14
RF 15
RF 16

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/072753

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q21/00 H01Q1/24 H01Q21/24 H01Q21/28
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018/060663 A1 (ZONEART NETWORKS LTD [GB]) 5 April 2018 (2018-04-05) figure 3b figure 22 figure 25 figure 26 page 27, line 19 - line 29 page 69, line 19 - page 70, line 2 page 70, line 20 - line 28 page 71, line 22 - line 27 page 72, line 1 - line 11 -----	1,2,5-9, 11,13-15
X	US 2009/146904 A1 (SHI SHAWN [US] ET AL) 11 June 2009 (2009-06-11) figure 3 paragraph [0023] - paragraph [0033] ----- -/--	1,13

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 April 2021	16/04/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kalialakis, Christos

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/107474 A2 (CISCO TECH IND [US]) 24 December 2003 (2003-12-24) figure 1 figure 2 page 4, line 3 - page 5, line 15	1,13
X	US 2019/252795 A1 (MURATA TOMOHIRO [JP] ET AL) 15 August 2019 (2019-08-15) figure 6 figure 7A figure 7B figure 7C paragraph [0099] - paragraph [0109]	1,13
X	EISENBEIS JOERG ET AL: "Low Complexity Antenna Array Concept Using Overlapped Subarray Based Hybrid Beamforming", 2018 ASIA-PACIFIC MICROWAVE CONFERENCE (APMC), IEICE, 6 November 2018 (2018-11-06), pages 669-671, XP033500323, DOI: 10.23919/APMC.2018.8617412 [retrieved on 2019-01-16] figure 1 figure 2 Section I; last paragraph Section III Section II; paragraph [first]	1,3,4, 10,12, 13,16

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/072753

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		WO 2018060663 A1	05-04-2018
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		US 2009146904 A1	11-06-2009
WO 03107474 A2	24-12-2003	AU 2003234668 A1	31-12-2003
		WO 03107474 A2	24-12-2003
US 2019252795 A1	15-08-2019	CN 110165393 A	23-08-2019
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		US 2019252795 A1	15-08-2019