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(54) MICROSTRIP ANTENNA, ANTENNA ARRAY AND METHOD OF MANUFACTURING MICROSTRIP ANTENNA

(71) Applicant: **Alcatel Lucent**, Nozay (FR)

(72) Inventors: **Fei Gao**, Shanghai (CN); **Jinxing Lu**, Shanghai (CN); **Wei Wang**, Shanghai (CN); **Gang Shen**, Shanghai (CN)

(73) Assignee: **Alcatel Lucent**, Nozay (FR)

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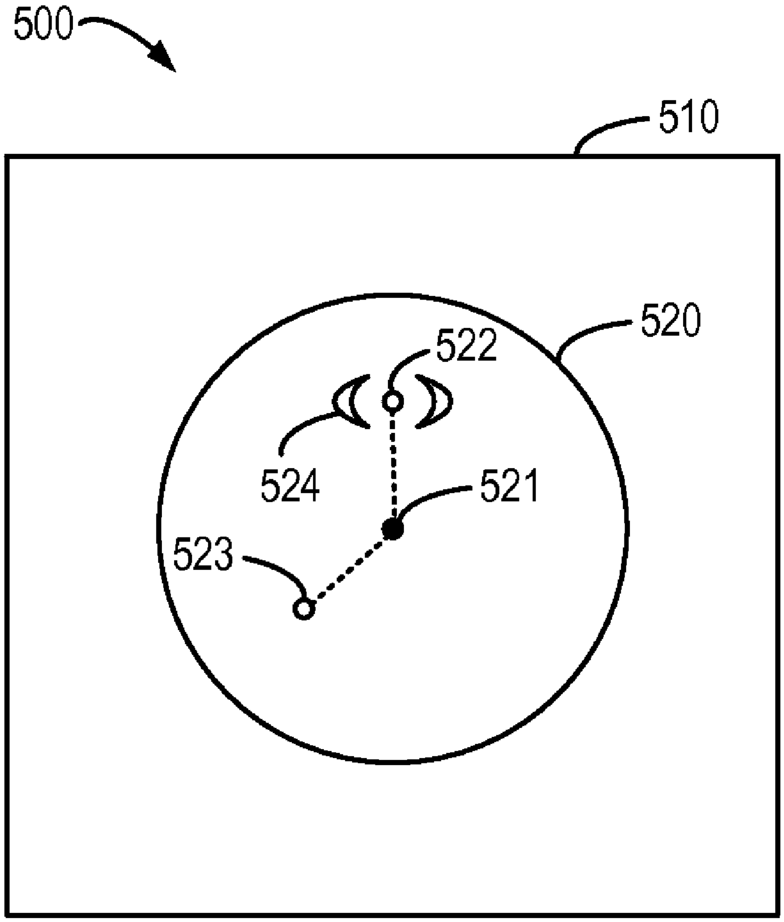
(57) ABSTRACT

Embodiments of the present disclosure provide a microstrip antenna and an antenna array. The microstrip antenna includes a ground plane disposed on a first surface of a substrate of the microstrip antenna; a metal patch disposed on a second surface of the substrate opposite to the first surface; a feeding point disposed on the metal patch such that the microstrip antenna has a first resonant frequency; and a shorting point disposed on the metal patch such that the microstrip antenna has a second resonant frequency different from the first resonant frequency. The microstrip antenna according to embodiments of the present disclosure has a wide bandwidth, a low profile, a high gain, a small size, and a simple structure.



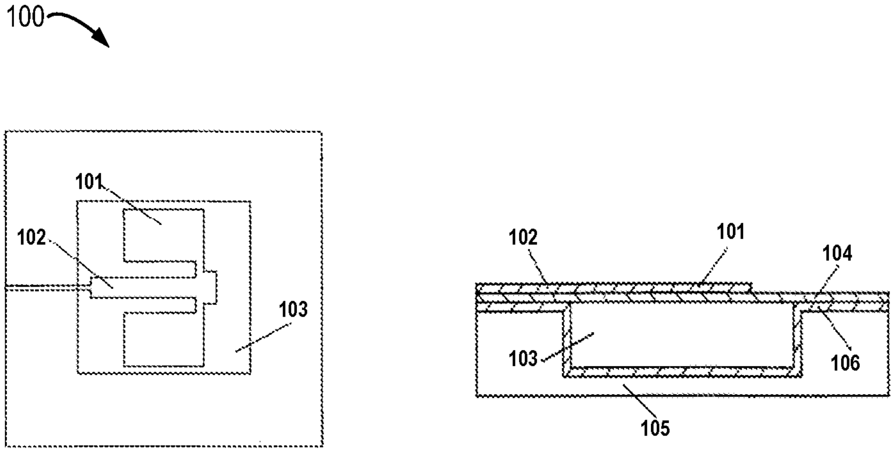

100
101
102
103
102
101
104
103
106
105

FIG. 1

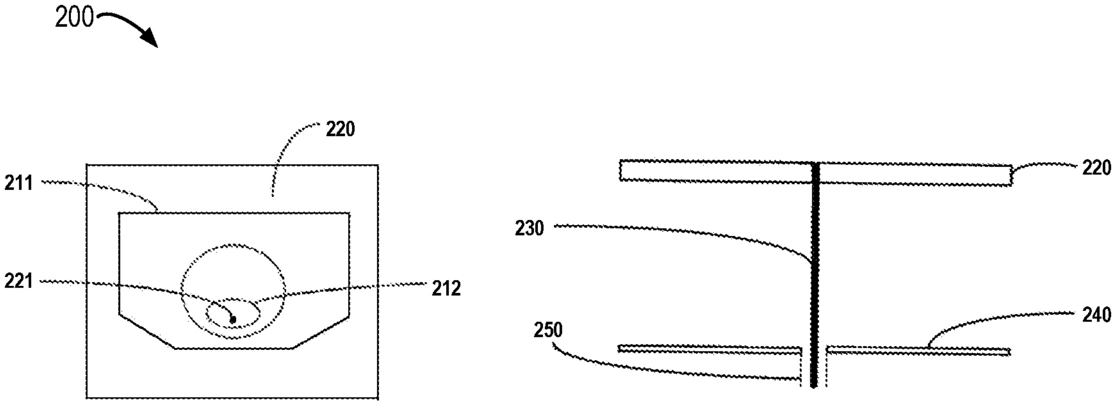

200
220
211
221
212
220
230
250
240

FIG. 2

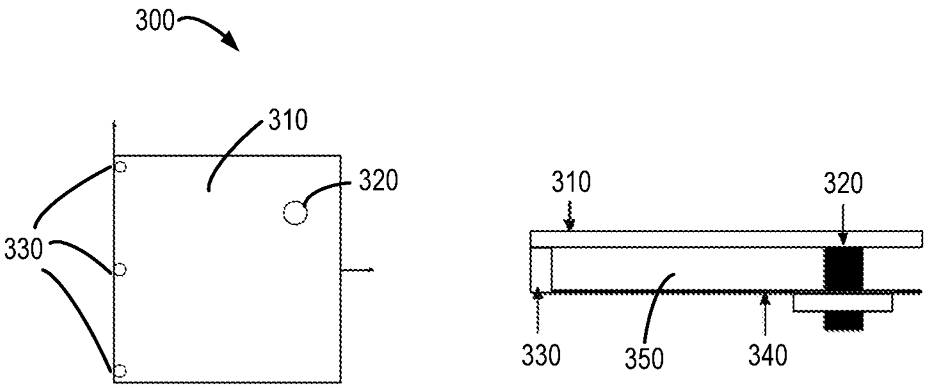

300
310
320
330
310
320
330
350
340

FIG. 3

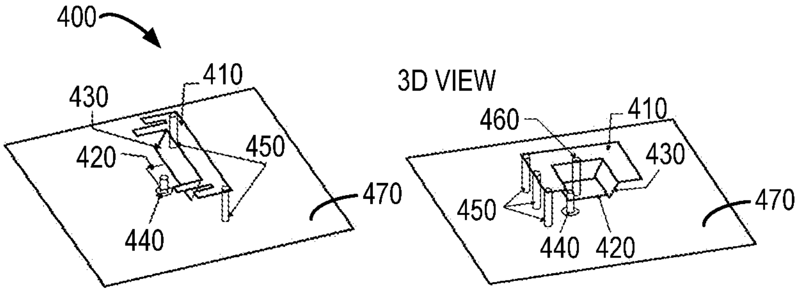

400
410
430
420
450
470
440
3D VIEW
460
410
430
450
470
440
420

FIG. 4

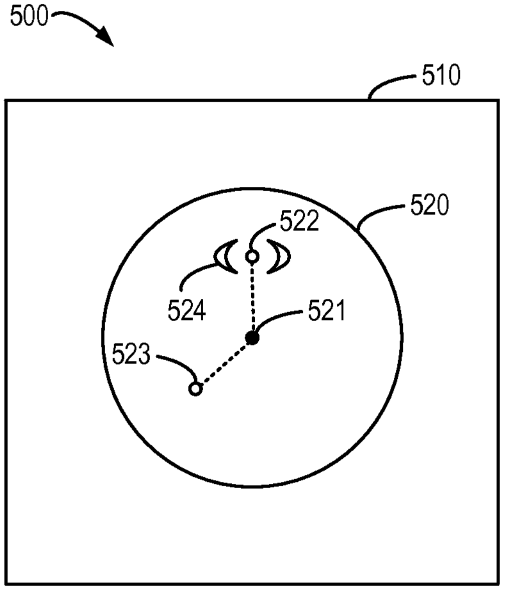


FIG. 5

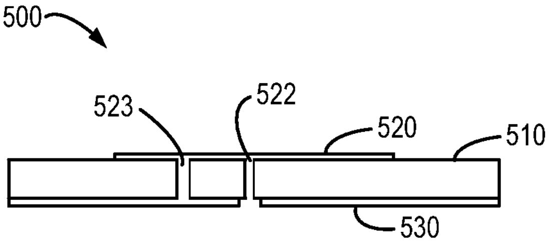


FIG. 6

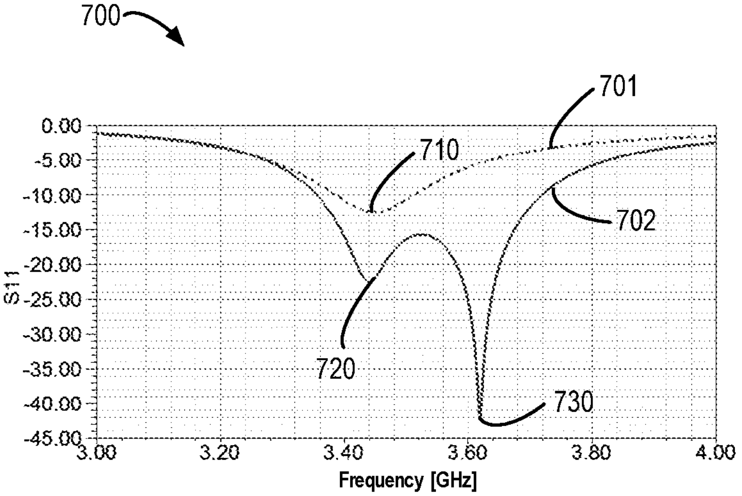

700
701
710
702
720
730
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
S11
3.00
3.20
3.40
3.60
3.80
4.00
Frequency [GHz]

FIG. 7

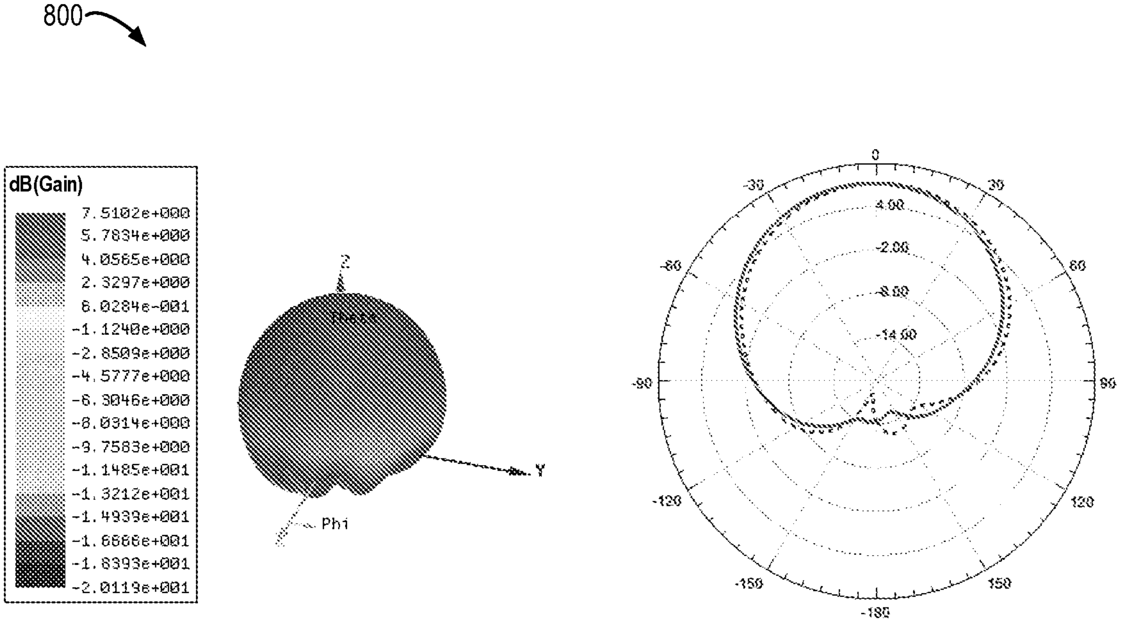

800
dB(Gain)
7.5102e+000
5.7834e+000
4.0565e+000
2.3297e+000
6.0284e-001
-1.1240e+000
-2.8509e+000
-4.5777e+000
-6.3046e+000
-8.0314e+000
-9.7583e+000
-1.1485e+001
-1.3212e+001
-1.4939e+001
-1.6666e+001
-1.8393e+001
-2.0119e+001
Z
Theta
Y
Phi
0
-30
30
-60
60
-90
90
-120
120
-150
150
-180
4.00
-2.00
-8.00
-14.00

FIG. 8

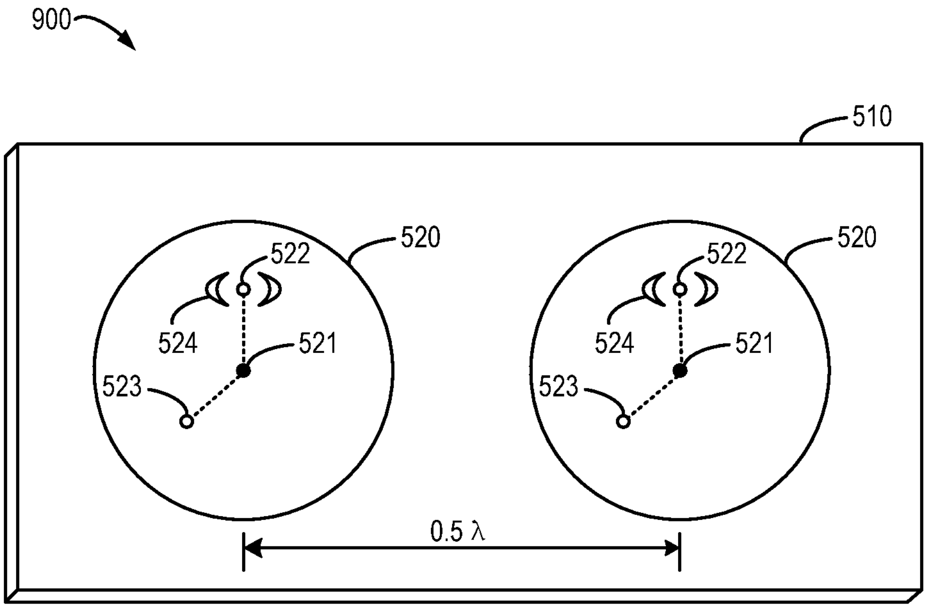

900
510
520
522
524
521
523
520
522
524
521
523
0.5 λ

FIG. 9

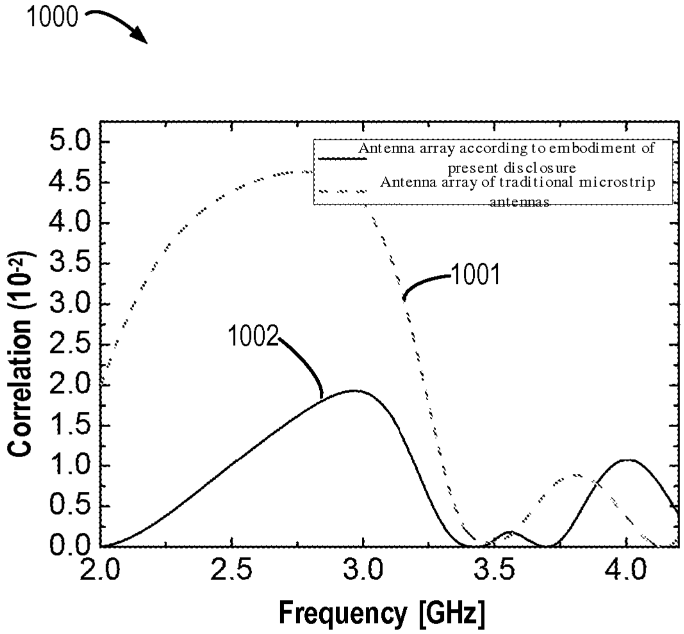

1000
Antenna array according to embodiment of present disclosure
Antenna array of traditional microstrip antennas
1001
1002
Correlation (10^{-2})
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.0
2.5
3.0
3.5
4.0
Frequency [GHz]

FIG. 10

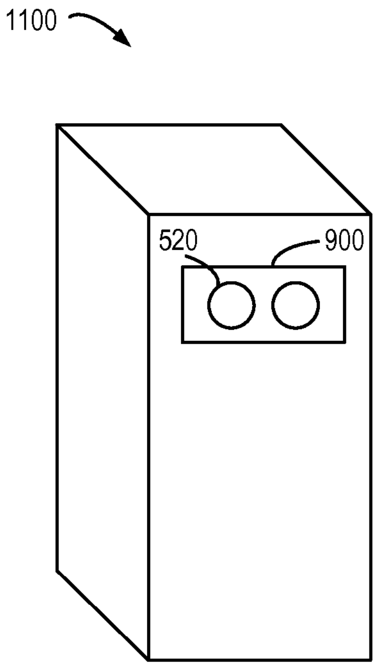

1100
520
900

FIG. 11

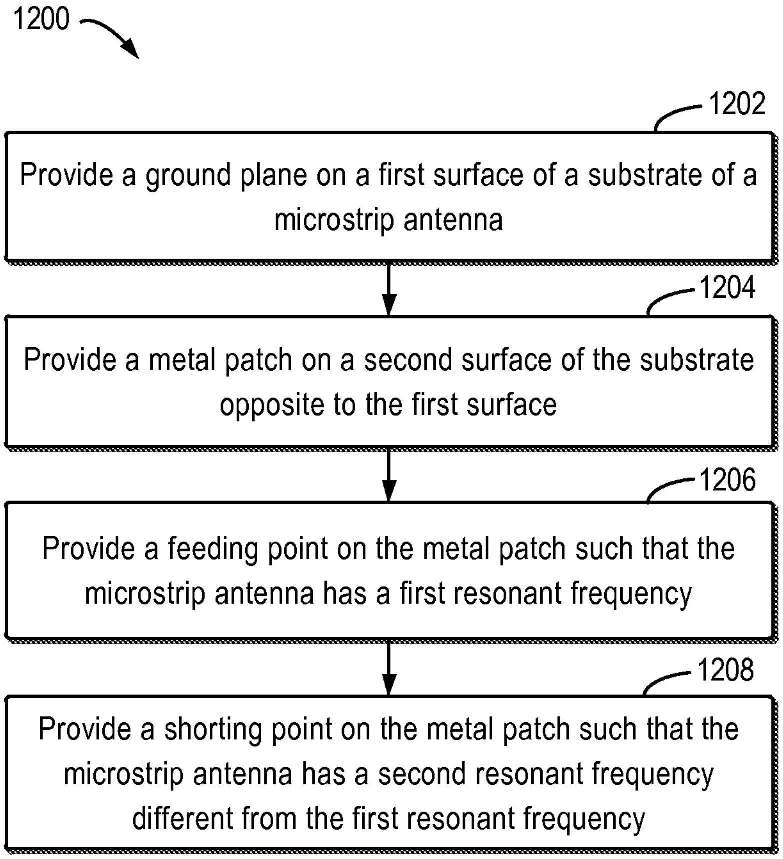

1200
1202
Provide a ground plane on a first surface of a substrate of a microstrip antenna
1204
Provide a metal patch on a second surface of the substrate opposite to the first surface
1206
Provide a feeding point on the metal patch such that the microstrip antenna has a first resonant frequency
1208
Provide a shorting point on the metal patch such that the microstrip antenna has a second resonant frequency different from the first resonant frequency

FIG. 12

MICROSTRIP ANTENNA, ANTENNA ARRAY AND METHOD OF MANUFACTURING MICROSTRIP ANTENNA

FIELD

[0001] The present disclosure generally relates to antennas, and more particularly, to a microstrip antenna, an antenna array and a method of manufacturing a microstrip antenna.

BACKGROUND

[0002] Wideband low-profile microstrip antenna plays a key role for Multiple Input Multiple Output (MIMO) applications, especially the Massive MIMO in 5G where a large number of antenna elements are employed and each antenna element has a small occupying area and a wide bandwidth.

[0003] Microstrip antennas are lightweight, low profile and low cost devices typically with a cylindrical and conformal structure suitable for replacing bulky antennas. However, traditional microstrip antennas suffer from a narrow bandwidth and a wideband microstrip antenna usually has a high profile and uses air as the substrate thereby increasing the manufacturing complexity. Some of wideband microstrip antennas have a relatively large size due to loaded slots or have a relatively low gain. In short, existing wideband microstrip antennas have various defects in different aspects.

SUMMARY

[0004] Embodiments of the present disclosure provide a microstrip antenna, an antenna array, and a method of manufacturing a microstrip antenna.

[0005] According to a first aspect of the present disclosure, a microstrip antenna is provided. The microstrip antenna includes a ground plane disposed on a first surface of a substrate of the microstrip antenna; a metal patch disposed on a second surface of the substrate opposite to the first surface; a feeding point disposed on the metal patch such that the microstrip antenna has a first resonant frequency; and a shorting point disposed on the metal patch such that the microstrip antenna has a second resonant frequency different from the first resonant frequency.

[0006] In some embodiments, an angle between a line from the shorting point to a center point of the metal patch and a line from the feeding point to the center point may be greater than 90 degrees and less than 180 degrees. In some embodiments, the shorting point may include a via connected to the ground plane.

[0007] In some embodiments, the microstrip antenna may further include at least one slot disposed around the feeding point. In some embodiments, the at least one slot may include two slots that are substantially symmetrical with respect to the line from the feeding point to the center point.

[0008] In some embodiments, the metal patch may include a circular metal patch. In some embodiments, the microstrip antenna may be fed via a coaxial cable.

[0009] In some embodiments, a thickness of the substrate may be smaller than about one tenth of a wavelength corresponding to a center frequency of the microstrip antenna. In some embodiments, a size of the metal patch may be smaller than about a half of a wavelength corresponding to the center frequency of the microstrip antenna.

[0010] According to a second aspect of the present disclosure, an antenna array is provided. The antenna array includes a plurality of microstrip antennas according to the first aspect of the present disclosure.

[0011] In some embodiments, an arrangement of the plurality of microstrip antennas and positions of the shorting points of the respective microstrip antennas on the respective metal patches may be disposed cooperatively, such that propagation of a surface wave in the antenna array is reduced. In some embodiments, the antenna array may be used in a multiple input multiple output (MIMO) system.

[0012] According to a third aspect of the present disclosure, a method of manufacturing a microstrip antenna is provided. The method includes providing a ground plane on a first surface of a substrate of the microstrip antenna; providing a metal patch on a second surface of the substrate opposite to the first surface; providing a feeding point on the metal patch, such that the microstrip antenna has a first resonant frequency; and providing a shorting point on the metal patch, such that the microstrip antenna has a second resonant frequency different from the first resonant frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Through the following detailed description with reference to the accompanying drawings, the above and other objectives, features, and advantages of embodiments of the present disclosure will become more apparent. Several example embodiments of the present disclosure will be illustrated by way of example but not limitation in the drawings in which:

[0014] FIG. **1** schematically shows a structure diagram of a traditional microstrip antenna;

[0015] FIG. **2** schematically shows a structure diagram of another traditional microstrip antenna;

[0016] FIG. **3** schematically shows a structure diagram of a further traditional microstrip antenna;

[0017] FIG. **4** schematically shows a structure diagram of a still further traditional microstrip antenna;

[0018] FIG. **5** schematically shows a plan view of a microstrip antenna according to an embodiment of the present disclosure;

[0019] FIG. **6** schematically shows a side view of a microstrip antenna according to an embodiment of the present disclosure;

[0020] FIG. **7** schematically shows a graph of reflection coefficients of a microstrip antenna according to an embodiment of the present disclosure in the presence/absence of a shorting point;

[0021] FIG. **8** schematically shows a diagram of a radiation pattern of a microstrip antenna according to an embodiment of the present disclosure;

[0022] FIG. **9** schematically shows an antenna array according to an embodiment of the present disclosure;

[0023] FIG. **10** schematically shows a comparison graph of a correlation coefficient varying with the frequency for an antenna array according to an embodiment of the present disclosure and an antenna array formed by traditional microstrip antennas;

[0024] FIG. **11** schematically shows a diagram in which an antenna array according to an embodiment of the present disclosure can be mounted on a surface of a small base station; and

[0025] FIG. **12** schematically shows a flow chart of a method of manufacturing a microstrip antenna according to an embodiment of the present disclosure.

[0026] Throughout the drawings, same or similar reference numbers are used to represent same or similar elements.

DETAILED DESCRIPTION OF EMBODIMENTS

[0027] Principles and spirits of the present disclosure will now be described with reference to various example embodiments illustrated in the drawings. It should be appreciated that description of those embodiments is merely to enable those skilled in the art to better understand and further implement example embodiments disclosed herein and is not intended for limiting the scope disclosed herein in any manner.

[0028] As mentioned above, microstrip antennas are lightweight, low profile and low cost devices with a cylindrical and conformal structure suitable for replacing bulky antennas. However, a microstrip antenna typically has an inherently narrow operating frequency bandwidth, for example, less than 5% of the center frequency, which limits more widespread usage of microstrip antennas.

[0029] In traditional solutions, a way to extend the bandwidth of a microstrip antenna is increasing the thickness of the substrate with low effective permittivity. This traditional solution will be discussed below with reference to FIGS. **1** and **2**.

[0030] FIG. **1** schematically shows a structure diagram of a traditional microstrip antenna **100**. Specifically, the left figure is a plan view of the microstrip antenna **100** while the right figure is a sectional view of the microstrip antenna **100**. As shown in FIG. **1**, the microstrip antenna **100** may include a microstrip patch **101**, a microstrip line **102**, a back cavity **103**, a microstrip dielectric plate **104**, a structural support plate **105**, and a metal ground **106**.

[0031] FIG. **2** schematically shows a structure diagram of another traditional microstrip antenna **200**. Specifically, the left figure is a plan view of the microstrip antenna **200** while the right figure is a sectional view of the microstrip antenna **200**. As shown in FIG. **2**, the microstrip antenna **200** may include a rectangular corner-truncated patch **211** with a hollow center portion, an elliptic patch **212**, a feeding point **221**, a dielectric plate **220**, a coaxial probe **230**, a ground plate **240**, and a coaxial line feeding ground terminal **250**.

[0032] It can be seen that the wideband microstrip antenna **100** in FIG. **1** extends the bandwidth by adding an air cavity **103**, which will increase the thickness and manufacturing cost of the microstrip antenna **100**. The microstrip antenna **200** in FIG. **2** simply increases the thickness of the microstrip antenna **200** and uses slots between the rectangular corner-truncated patch **211** and the elliptic patch **212** to cancel the inductance introduced by the long feeding probe **230**. These methods in FIGS. **1** and **2** will lead to a high profile microstrip antenna and an increased manufacturing cost. In addition, the air cavity **103** may also limit the feeding network arrangement as it is on the back of the microstrip patch **101**.

[0033] In traditional solutions, another solution of extending the bandwidth of the microstrip antenna is employing via loading or resistor loading. This traditional solution will be discussed below with reference to FIGS. **3** and **4**.

[0034] FIG. **3** schematically shows a structure diagram of a further traditional microstrip antenna **300**. Specifically, the left figure is a plan view of the microstrip antenna **300** while the right figure is a sectional view of the microstrip antenna **300**. As shown in FIG. **3**, the microstrip antenna **300** may include a square patch **310**, a probe feeding **320**, a short pin **330**, a ground plane **340** and an air-filled substrate **350**, etc.

[0035] FIG. **4** schematically shows a structure diagram of a still further traditional microstrip antenna **400**. Specifically, the left figure is a plan view of the microstrip antenna **400** while the right figure is a three-dimensional (3D) view of the microstrip antenna **400**. As shown in FIG. **4**, the microstrip antenna **400** may include an upper patch **410**, a lower patch **420**, a folded slope-shaped portion **430**, a probe feeding **440**, a short pin **450**, a center pin **460** and a ground plane **470**, etc.

[0036] It can be seen that the via loading solution in the microstrip antennas **300** and **400** of FIGS. **3** and **4** uses several vias, which will reduce the antenna gain. Similarly, resistor loading can also increase the bandwidth, but it also decreases the radiation efficiency and antenna gain.

[0037] Additionally, in traditional solutions, slots can be also introduced into the radiator to increase the bandwidth of the microstrip antenna, for example, U-shape slots and rectangular slots. These slots usually increase the size of the antenna, but the bandwidth is significantly enhanced along with substrate thickness. Thus, this configuration also suffers from a high cost. Furthermore, the introduction of slots usually excites unnecessary surface waves and reduces performance of a microstrip antenna in a MIMO system. Because an antenna should be designed to be small for MIMO or massive MIMO application, a large size of each element will affect the antenna array arrangement. Although proximity feeding can increase the bandwidth for a relatively thin microstrip antenna, this arrangement is too complicated as it includes several layers.

[0038] Therefore, the existing solutions cannot provide a low-cost microstrip antenna with a thin substrate, a wide bandwidth, a small size and a high gain. In view of this, embodiments of the present disclosure provide a microstrip antenna, which increases the bandwidth of a single-layer microstrip antenna without impacting the thickness, gain and patch geometry of the microstrip antenna. The arrangement of a feeding point and a shorting point probe enhances performance of the microstrip antenna in a MIMO system. The microstrip antenna according to the embodiments of the present disclosure has a low profile, a small size, a wide bandwidth and a high gain, and further it is simple in structure and effective in the cost. Thus, it can be widely used, for example, in MIMO system, especially in massive MIMO system in 5G communications. The structure of the microstrip antenna according to embodiments of the present disclosure will be described below in details with reference to FIGS. **5** and **6**.

[0039] FIGS. **5** and **6** respectively show a plan view and a side view of a microstrip antenna **500** according to an embodiment of the present disclosure. As shown in FIGS. **5** and **6**, the microstrip antenna **500** includes a substrate **510** fabricated by any dielectric materials suitable for the microstrip antenna. For example, in some embodiments, the substrate **510** may have permittivity of 2.55 and dielectric loss tangent of 0.0019. In some embodiments, the thickness of the substrate **510** may be smaller than about one tenth of a wavelength corresponding to the center frequency of the microstrip antenna **500**, so as to achieve a low profile of the microstrip antenna **500**. For instance, in case the operating frequency band of the microstrip antenna **500** is designed to cover 3.4-3.6 GHz of the long term evolution (LTE) band, the thickness of the substrate **510** may be approximately 3 mm. It is noted that the above described specific values are only examples and not intended to limit the scope of the present disclosure in any manner. Dependent on specific application environments and needs, any other appropriate values are viable.

[0040] Further, the microstrip antenna **500** also includes a ground plane **530** disposed on a first surface of the substrate **510**. In FIG. **5**, the first surface of the substrate **510** refers to a bottom surface of the substrate **510**, which is not shown. In FIG. **6**, the first surface of the substrate **510** is depicted as the bottom surface at the lower side of the substrate **510**. Although FIG. **6** depicts the ground plane **530** as completely covering the first surface of the substrate **510**, other covering manners are also possible. For example, the ground plane **530** covers only a portion of the first surface of the substrate **510** or forms a pattern, etc.

[0041] Additionally, the microstrip antenna **500** also includes a metal patch **520**. As shown in the drawings, the metal patch **520** is disposed on a second surface of the substrate **510** opposite to the first surface. In FIG. **5**, the second surface of the substrate **510** is shown as a top surface of the substrate **510**. In FIG. **6**, the second surface of the substrate **510** is depicted as a top surface at the upper side of the substrate **510**. It should be understood that although the metal patch **520** is described as a circular metal patch in FIG. **5**, technical solutions of the embodiments of the present disclosure are also applicable to metal patch **520** in other shapes, for example, rectangular metal patch, square metal patch and so on. In some embodiments, the metal patch **520** may be sized to be smaller than about a half of a wavelength corresponding to the center frequency of the microstrip antenna **500**, such that the metal patch **520** will be more advantageous to be used in an antenna array arrangement of MIMO. For example, in case the operating frequency band of the microstrip antenna **500** is designed to cover the LTE band 3.4-3.6 GHz and the metal patch **520** is a circular metal patch, its radius can be 15 mm, that is 0.175 time of the wavelength at 3.5 GHz. Other center frequency values are also feasible and the scope of the present disclosure is not limited thereto.

[0042] Moreover, the microstrip antenna **500** also includes a feeding point **522** arranged on the metal patch **520**, such that the microstrip antenna **500** has a first resonant frequency. Further, the microstrip antenna **500** also includes a shorting point **523** that is also arranged on the metal patch **520**, such that the microstrip antenna **500** has a second resonant frequency different from the first frequency. In embodiments of the present disclosure, the shorting point **523** may miniaturize the microstrip antenna **500** and the introduction of the shorting point **523** can also enable the microstrip antenna **500** to have a second resonant frequency different from the first resonant frequency. In this way, the operating bandwidth of the microstrip antenna **500** may be significantly extended without increasing the thickness of the microstrip antenna **500** or reducing the gain. The first resonant frequency and the second resonant frequency of the microstrip antenna **500** will be described below in details with reference to FIG. **7**.

[0043] FIG. **7** schematically shows a graph **700** of reflection coefficients of a microstrip antenna **500** according to an embodiment of the present disclosure in the presence/absence of a shorting point **523**. In the graph **700** of FIG. **7**, the horizontal axis represents frequency in the unit of gigahertz (GHz) and the vertical axis represents the reflection coefficient S **11** in scattering parameters (S parameter) in the unit of decibel (dB). Furthermore, the dotted curve **701** represents the reflection coefficient curve of the microstrip antenna **500** without the shorting point **523**, whereas the solid curve **702** indicates the reflection coefficient curve of the microstrip antenna **500** with the shorting point **523**.

[0044] As shown in FIG. **7**, the microstrip antenna **500** has only one resonant frequency **710** in the absence of the shorting point **523**. In this event, the operating bandwidth of −10 dB is smaller than 4% of the center frequency in the specific example described by the graph **700**. In contrast, the microstrip antenna **500** has two resonant frequencies in the presence of the shorting point **523**, i.e., the first resonant frequency **720** and the second resonant frequency **730**, and thereby the operating bandwidth is significantly extended. For example, in the specific example described by the graph **700**, the operating bandwidth of −10 dB can be increased to about 3.35-3.73 GHz, that is approximate to 10.7% of the operating frequency, and the operating bandwidth of −15 dB can be increased to about 3.39-3.68 GHz, that is approximate to 8.2% of the operating frequency. In some embodiments, the reflection coefficient S11 of the microstrip antenna **500** may be adjusted by changing the position of the shorting point **523**.

[0045] Returning to FIGS. **5** and **6**, in some embodiments, an angle between a line from the shorting point **523** to a center point **521** of the metal patch **520** and a line from the feeding point **522** to the center point **521** can be greater than 90 degrees and less than 180 degrees. By implementing an angle of this range, the position relationship between the first resonant frequency **720** and the second resonant frequency **730** of the microstrip antenna **500** can be optimized, so as to increase the operating bandwidth of the microstrip antenna **500**. In some embodiments, the angle can be approximately 135 degrees. It should be noted that the above value range or value of the angle is not requisite. In other embodiments, the microstrip antenna **500** can be implemented using other angles.

[0046] In case the operating frequency band of the microstrip antenna **500** is designed to cover the LTE band 3.4-3.6 GHz, the distance between the feeding point **522** and the center point **521** can be 7 mm. When a rectangular coordinate system is built in the plane of the patch **520** by taking the center point **521** as the origin and the line from the feeding point **522** to the center point **521** as a vertical axis, the shorting point **523** can be located at the coordinates (3.7 mm, −4 mm) and the radius of the shorting point **523** can be 0.5 mm.

[0047] Although the shorting point **523** in FIG. **6** is depicted as including a via **523** connected to the ground plane **530**, embodiments of the present disclosure are not limited to this and other equivalent alternatives can also be employed to implement the shorting point **523**. Furthermore, in some embodiments, the microstrip antenna **500** may be fed via a coaxial cable (not shown). For example, a 50Ω coaxial cable may be used to feed the microstrip antenna **500** on the second surface of the substrate **510**. This feeding manner may be advantageous for microstrip antennas **500** forming an antenna array. In these embodiments, in order to feed the microstrip antenna **500**, an inner conductor of the coaxial cable can be connected to the feeding point **522**

while the outer conductor of the coaxial cable can be connected to the ground plane **530**. However, embodiments of the present disclosure are not limited to this and other equivalent alternatives can also be used for feeding, for example, feeding through a microstrip line and so on.

[0048] Continuing to refer to FIG. **5**, the microstrip antenna **500** may further include at least one slot **524**. According to embodiments of the present disclosure, the at least one slot **524** can be arranged around the feeding point **522**. The at least one slot **524** can facilitate the formation of the second resonant frequency of the microstrip antenna **500** and reduce propagation of surface waves in the antenna array in the scenario where the microstrip antenna **500** is used to form an antenna array. Besides, the at least one slot **524** may be used to compensate the probe inductance in the microstrip antenna **500** and can be disposed in a manner of reducing damage to the radiation currents as much as possible, so as to not influence the radiation efficiency of the microstrip antenna **500**. In some embodiments, the at least one slot **524** may include two slots that are substantially symmetrical with respect to the line from the feeding point **522** to the center point **521**. It should be noted that the slot **524** is not indispensable to the microstrip antenna **500** of embodiments of the present disclosure, and the microstrip antenna **500** may also be implemented without the slot **524**.

[0049] FIG. **8** schematically shows a diagram **800** of a radiation pattern of the microstrip antenna according to an embodiment of the present disclosure. In the specific simulation process as depicted in FIG. **8**, the operating frequency band of the microstrip antenna **500** is designed to cover the LTE band 3.4-3.6 GHz, the distance between the feeding point **522** and the center point **521** is 7 mm, the shorting point **523** is located at the coordinates (3.7 mm, −4 mm) in a rectangular coordinate system built in the plane of the patch **520** by taking the center point **521** as the origin and the line from the feeding point **522** to the center point **521** as a vertical axis, the radius of the shorting point **523** is 0.5 mm, and the substrate **510** has permittivity of 2.55, a dielectric loss tangent of 0.0019 and a thickness of 3 mm. As shown in FIG. **8**, the simulation gain of the microstrip antenna **500** is 7.5 dB, which is substantially equivalent to a simulated gain of 7.6 dB for a traditional circular microstrip antenna having a narrow bandwidth. Additionally, the introduction of the shorting point **523** (for example, a shorting via) causes a slight asymmetry of the radiation pattern, and the bandwidth of 3 dB is from −45 degrees to −36 degrees. However, the impact on the performance of the microstrip antenna **500** is negligible.

[0050] Accordingly, the microstrip antenna **500** according to embodiments of the present disclosure achieves the advantages of a thin substrate, a wide bandwidth, a small size and low cost while realizing a high gain. The advantageous features make the microstrip antenna **500** particularly beneficial to form an antenna array in order to be used in a MIMO or massive MIMO application.

[0051] FIG. **9** schematically shows an antenna array **900** according to an embodiment of the present disclosure. As shown in FIG. **9**, the antenna array **900** may include a plurality of microstrip antennas **500**, each of which may include a common substrate **510** and respective metal patches **520**. Although the antenna array **900** in FIG. **9** is depicted as including two microstrip antennas **500**, the antenna array **900** can be formed by more microstrip antennas **500** in other embodiments. In addition, the antenna array **900** can be used in a multiple input multiple output MIMO system.

[0052] In some embodiments, the arrangement of the plurality of microstrip antennas **500** in the antenna array **900** and the positions of the shorting point **523** of the respective microstrip antennas **500** on the respective metal patches **520** can be cooperatively arranged, so as to reduce propagation of surface waves in the antenna array **900**. In this way, the performance of the antenna array **900** may be further improved. For example, as shown in FIG. **9**, the plurality of microstrip antennas **500** can be disposed side by side and the distance between each other can be configured as about a half of the wavelength of the center frequency of the microstrip antenna **500**. Hereinafter, the performance advantages of the antenna array **900** according to embodiments of the present disclosure over an antenna array formed by traditional microstrip antennas will be described with reference to FIG. **10**.

[0053] FIG. **10** schematically shows a comparison graph **1000** of a correlation coefficient varying with the frequency for the antenna array **900** according to an embodiment of the present disclosure and an antenna array formed by traditional microstrip antennas. In FIG. **10**, S parameters are employed to calculate the correlation.

[0054] As shown in FIG. **10**, the dotted curve **1001** represents a correlation curve between microstrip antennas in the antenna array formed by traditional microstrip antennas, while the solid curve **1002** represents a correlation curve between microstrip antennas **500** in the antenna array **900** formed by the microstrip antennas **500** according to embodiments of the present disclosure. It can be seen from FIG. **10** that the microstrip antennas **500** increase the bandwidth and maintain a very low correlation coefficient in the formed antenna array **900**, and thus significantly improving the performance of the antenna array **900** compared with the traditional antenna array.

[0055] As mentioned above, the microstrip antenna **500** according to embodiments of the present disclosure has a wide bandwidth and can keep a very low correlation coefficient in the antenna array **900**. The small size and low profile may enable the microstrip antenna **500** to be mounted on any surfaces, which makes a related product more attractive.

[0056] FIG. **11** schematically shows a diagram in which the antenna array **900** according to an embodiment of the present disclosure can be mounted on a surface of a small base station **1100**. As shown in FIG. **11**, the antenna array **900** including the patch **520** may be arranged on a surface of the small base station **1100**. Such an arrangement can improve performance of a MIMO system. Additionally, the antenna array **900** may also be deployed around the small base station **1100** to realize a large range of coverage.

[0057] FIG. **12** schematically shows a flow chart of a method **1200** of manufacturing the microstrip antenna **500** according to embodiments of the present disclosure. As shown in FIG. **12**, at **1202**, a ground plane **530** is disposed on a first surface of a substrate **510** of the microstrip antenna **500**. At **1204**, a metal patch **520** is disposed on a second surface of the substrate **510** opposite to the first surface. At **1206**, a feeding point **522** is disposed on the metal patch **520**, such that the microstrip antenna **500** has a first resonant frequency. At **1208**, a shorting point **523** is disposed on the metal patch **520**, such that the microstrip antenna **500** has a second resonant frequency different from the first resonant frequency.

[0058] In some embodiments, providing the shorting point **523** on the metal patch **520** may include providing the shorting point **523** such that an angle between a line from the shorting point **523** to a center point **521** of the metal patch **520** and the line from the feeding point **522** to the center point **521** is greater than 90 degrees and less than 180 degrees.

[0059] In some embodiments, providing the shorting point **523** may include providing a via connected to the ground plane. In some embodiments, at least one slot **524** may be disposed around the feeding point **522**. In some embodiments, providing the at least one slot **524** may include providing two slots that are substantially symmetrical with respect to the line from the feeding point **522** to the center point **521**.

[0060] In some embodiments, the metal patch **520** may include a circular metal patch. In some embodiments, the microstrip antenna **500** may be fed via a coaxial cable. In some embodiments, the substrate **510** with a thickness smaller than about one tenth of a wavelength corresponding to the center frequency of the microstrip antenna **500** may be provided. In some embodiments, providing the metal patch **520** may include providing the metal patch **520** having a size smaller than about a half of the wavelength corresponding to the center frequency of the microstrip antenna **500**.

[0061] Embodiments of the present disclosure provide a wideband microstrip antenna with a low profile, a high gain, a small size and a simple structure. The proposed microstrip antennas exhibit a wide bandwidth and a very low correlation coefficient in an antenna array. It can be used in the MIMO system of 5G and similar applications.

[0062] The microstrip antenna provided by the embodiments of the present disclosure achieves innovative improvements in the following five aspects. The first aspect is the thin substrate, which facilitates integration of the microstrip antenna with other circuits and reduces manufacturing cost. Then, the proposed microstrip antenna has a small size without compromising the gain, which provides a flexible arrangement in the MIMO system. Thirdly, the proposed microstrip antenna is single-layered and such a structure is simple and easy to make. Fourthly, the proposed microstrip antenna uses less via loading, which can be used to increase the operating bandwidth in the embodiments of the present disclosure. However, less via loading can reduce the manufacturing cost with less impact on the gain. Fifthly, the proposed microstirp antenna can radiate two orthogonal polarized waves simultaneously, which may reduce polarization mismatch in communications.

[0063] Compared with the traditional wideband microstrip antennas, the proposed microstrip antenna has several advantages. The proposed microstrip antenna has a rather low profile and the thickness of the antenna can be only 3 mm in practical use, which is approximate to 0.035 time of center frequency λ whereas most of traditional wideband microstrip antennas usually have a thickness of 0.1λ. The proposed microstrip antenna is single-layered, and the traditional single-layered wideband microstrip antennas typically have a high profile or complicated assembly due to the need for an air cavity, whereas the proposed antenna has the same simple structure as traditional narrow band microstrip antennas. The proposed microstrip antenna also has a small size and can be around 0.35 time of the center frequency wavelength λ in specific application scenario. In contrast, the existing wideband microstrip antennas using slots increases the size of the microstrip antenna. The small size enables the proposed antenna to have more choices in the MIMO antenna array arrangement. The proposed microstrip antenna has a low correlation coefficient in an antenna array, which will provide better MIMO performance. At last, the proposed microstrip antenna has a quite wide bandwidth compared with other traditional microstrip antennas with a low profile, a small size and a high gain.

[0064] In the description about embodiments of the present disclosure, the term “includes” and its variants are to be read as open-ended terms that mean “includes, but is not limited to.” The term “based on” is to be read as “based at least in part on.” The terms “one example embodiment” and “the example embodiment” are to be read as “at least one example embodiment.”

[0065] Although the present disclosure has been described with reference to several specific embodiments, it should be understood that the present disclosure is not limited to the specific embodiments disclosed herein. Particularly, the described contents of the present disclosure aim to encompass various modifications and equivalent arrangements included within the spirit and scope of the attached claims.

1. A microstrip antenna, comprising:
a ground plane disposed on a first surface of a substrate of the microstrip antenna;
a metal patch disposed on a second surface of the substrate opposite to the first surface;
a feeding point disposed on the metal patch such that the microstrip antenna has a first resonant frequency; and
a shorting point disposed on the metal patch such that the microstrip antenna has a second resonant frequency different from the first resonant frequency.

2. The microstrip antenna of claim **1**, wherein an angle between a line from the shorting point to a center point of the metal patch and a line from the feeding point to the center point is greater than 90 degrees and less than 180 degrees.

3. The microstrip antenna of claim **1**, wherein the shorting point includes a via connected to the ground plane.

4. The microstrip antenna of claim **1**, further comprising:
at least one slot disposed around the feeding point.

5. The microstrip antenna of claim **4**, wherein the at least one slot includes two slots that are substantially symmetrical with respect to a line from the feeding point to a center point of the metal patch.

6. The microstrip antenna of claim **1**, wherein the metal patch includes a circular metal patch.

7. The microstrip antenna of claim **1**, wherein the microstrip antenna is fed via a coaxial cable.

8. The microstrip antenna of claim **1**, wherein a thickness of the substrate is smaller than about one tenth of a wavelength corresponding to a center frequency of the microstrip antenna.

9. The microstrip antenna of claim **1**, wherein a size of the metal patch is smaller than about a half of a wavelength corresponding to a center frequency of the microstrip antenna.

10. An antenna array, including a plurality of microstrip antennas according to claim **1**.

11. The antenna array of claim **10**, wherein an arrangement of the plurality of microstrip antennas and positions of the shorting points of the respective microstrip antennas on the respective metal patches are disposed cooperatively, such that propagation of a surface wave in the antenna array is reduced.

12. The antenna array of claim **10**, wherein the antenna array is used in a multiple input multiple output (MIMO) system.

13. A method of manufacturing a microstrip antenna, comprising:

providing a ground plane on a first surface of a substrate of the microstrip antenna;

providing a metal patch on a second surface of the substrate opposite to the first surface;

providing a feeding point on the metal patch such that the microstrip antenna has a first resonant frequency; and

providing a shorting point on the metal patch such that the microstrip antenna has a second resonant frequency different from the first resonant frequency.

14. The method of claim **13**, wherein providing the shorting point on the metal patch comprises:

providing the shorting point such that an angle between a line from the shorting point to a center point of the metal patch and a line from the feeding point to the center point is greater than 90 degrees and less than 180 degrees.

15. (canceled)

16. The method of claim **13**, further comprising:

providing at least one slot around the feeding point.

17.-**21**. (canceled)

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