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(54) **FREQUENCY-SELECTIVE-SURFACE SUB-REFLECTOR WITH WIDEBAND MULTI ELEMENTS APPLIED TO SINGLE OFFSET ANTENNA**

(57) The current invention is a wideband multi-element frequency-selective-surface sub-reflector (100) with application to a single offset antenna. The wideband multi-element frequency-selective-surface sub-reflector (100) includes a circuit board (10), a first outer cover (20) and a second outer cover (30). The circuit board (10) includes an insulating layer (12), a first metal layer (14) and a second metal layer (16). The first metal layer (14) and the second metal layer (16) are placed on the two sides of the insulating layer (12), include respectively a plurality of double coupling hollow aperture elements (142, 162), and are used as two reflecting interface end-planes to form a resonant cavity. The first outer cover (20) and the second outer cover (30) are respectively arranged on surfaces of the first metal layer (14) and the second metal layer (16). The wideband multi-element frequency-selective-surface sub-reflector (100) reflects low frequency signals, and then a low frequency receiver (300) receives the reflected low frequency signals. High frequency signals penetrate the double coupling hollow aperture elements (142, 162) of the wideband multi-element frequency-selective-surface sub-reflector (100), enabling designed target signals to couple from an incoming side to a transmission side to achieve a feature of a high penetrability.

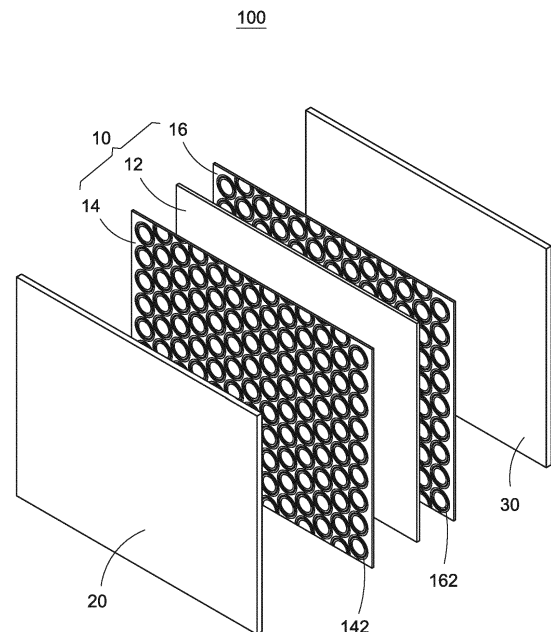


FIG.2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a frequency-selective-surface sub-reflector, and especially relates to a wideband multi-element frequency-selective-surface sub-reflector with application to a single offset antenna

Description of the Related Art

[0002] Currently in the market, the antenna system of a satellite television which is used to receive television programs through satellite broadcasting, mostly comprises a parabolic main reflector, a low frequency receiver (modified LNB), a high frequency transceiver (modified TRIA) and a related art frequency-selective-surface sub-reflector (FSS-SR). The related art frequency-selective-surface sub-reflector is combined with and placed between the low frequency receiver and the high frequency transceiver.

[0003] When receiving satellite television signals, the parabolic main reflector of the antenna system reflects the satellite television signals to the related art frequency-selective-surface sub-reflector. The related art frequency-selective-surface sub-reflector makes high frequency signals (K/Ka-band feed) of the satellite television signals penetrate and focus on the high frequency transceiver for reception, and the received high frequency signals are then transmitted to a decoder through a cable. Moreover, low frequency signals (Ku-band feed) reflected by the related art frequency-selective-surface sub-reflector focus on the low frequency receiver for reception.

[0004] When the antenna system receives the satellite television signals, the related art frequency-selective-surface sub-reflector is used as a filter, enabling the high frequency signals of the satellite television signals to penetrate through and the low frequency signals to reflect back. Currently, the related art frequency-selective-surface sub-reflector comprises a polystyrene (PS) layer, and each of the two sides of the polystyrene layer comprises a latticed metal layer (copper layer) with an epoxy glass cloth laminated board (FR4) deposited on the latticed metal layer's surface.

[0005] Due to dielectric materials used in, pattern designs of the metal layers on, and rough surface of copper foil with insufficient flatness used currently for metal layers of the related art frequency-selective-surface sub-reflector mentioned above, the energy loss could increase easily, affecting the penetrability of the high frequency signals.

SUMMARY OF THE INVENTION

[0006] Therefore, the main objective of the present invention is that the present invention uses a dielectric ma-

terial with a low dielectric constant (permittivity) and a low loss tangent value. As a result, the penetration rate (the transmission rate) of the electromagnetic waves through the frequency-selective-surface sub-reflector increases and the loss of the electromagnetic energy decreases. At the same time, the present invention adopts the pattern designs of double coupling elements, and uses two metal layers as two reflecting interface end-planes to form a resonant cavity to enhance and achieve the feature of high penetrability so that signals can be coupled from the incoming side direction to the transmission side direction effectively. Then, by appropriately adjusting the thickness of the dielectric materials and the widths of the complying elements, e.g., metal rings, the resonance bandwidth increases from narrowband to broadband. Moreover, the present invention selects the copper foils (which are suitable for high frequencies and have smoother surfaces) as the metal layers to reduce further the energy loss rate, and adds outer covers to prevent rusting.

[0007] In order to achieve the objective mentioned above, the present invention provides a wideband multi-element frequency-selective-surface sub-reflector with application to a single offset antenna. The frequency-selective-surface sub-reflector can be integrated in an antenna system and is arranged in a position between a high frequency transceiver and a low frequency receiver. The frequency-selective-surface sub-reflector includes a circuit board, a first outer cover and a second outer cover. The circuit board includes an insulating layer, a first metal layer and a second metal layer. The first metal layer and the second metal layer are placed on two sides of the insulating layer, comprise respectively a plurality of double coupling hollow aperture elements, and are used as two reflecting interface end-planes to form a resonant cavity. The first outer cover is arranged on a surface of the first metal layer of the circuit board. The second outer cover is arranged on the second metal layer of the circuit board. The frequency-selective-surface sub-reflector is configured to reflect low frequency signals that will be received by the low frequency receiver. The double coupling elements of the frequency-selective-surface sub-reflector are configured to couple designed high-frequency target signals from an incoming side direction to a transmission side direction with high transmittance or penetrability.

[0008] In an embodiment of the present invention, a double coupling element is concentric dual rings.

[0009] In an embodiment of the present invention, concentric dual rings include an inner ring and an outer ring.

[0010] In an embodiment of the present invention, a spacing of an outer-ring slot of the outer ring is 0.2mm~0.6mm; a radius of the outer ring is 0.9mm~1.5mm; a spacing of an inner-ring slot is 0.1mm~0.5mm; a radius of the inner ring is 0.1mm~0.6mm.

[0011] In an embodiment of the present invention, concentric dual rings are circular, quadrate, triangular or po-

lygonal.

[0012] In an embodiment of the present invention, an insulating layer is a dielectric material with a low dielectric constant and a low loss tangent value.

[0013] In an embodiment of the present invention, an insulating layer is a composite material composited by (namely, comprising) an epoxy resin and a glass fiber cloth.

[0014] In an embodiment of the present invention, a dielectric constant value of the composite material is about 3.5~4.0; a dielectric loss value of the composite material is about 0.005~0.007.

[0015] In an embodiment of the present invention, a dielectric constant value of the composite material is about 4.3~4.8; a dielectric loss value of the composite material is about 0.016~0.02.

[0016] In an embodiment of the present invention, a metal of the first metal layer is a copper foil; a metal of the second metal layer is a copper foil.

[0017] In an embodiment of the present invention, a height of the circuit board is 0.5mm~2.0mm.

[0018] In an embodiment of the present invention, a thickness of the first outer cover is 0.5mm~2.0mm; a thickness of the second outer cover is 0.5mm~2.0mm.

[0019] In an embodiment of the present invention, a structural periodic arrangement of the double coupling elements of the first metal layer and the second metal layer is a hexagonal close packed structure.

[0020] In an embodiment of the present invention, the hexagonal close packed structure is a hexagonal prism arrangement or a honeycomb type structure.

[0021] In an embodiment of the present invention, a value of lattice constant P of the frequency-selective-surface sub-reflector is about 3mm~5mm.

[0022] In an embodiment of the present invention, a dielectric constant of a material used in the first outer cover and the second outer cover is close to 1.

BRIEF DESCRIPTION OF DRAWING

[0023]

Fig. 1 shows a three-dimensional diagram of the structural appearance of the frequency-selective-surface sub-reflector of the present invention.

Fig. 2 shows an exploded view of the structure of the frequency-selective-surface sub-reflector of the present invention.

Fig. 3 shows a partial amplified view of the structural diagram of the first metal layer or the second metal layer of the circuit board of Fig. 2.

Fig. 4 shows an equivalent circuit diagram of the double coupling element (the concentric dual rings) of Fig. 3.

Fig. 5 shows another partial amplified view of the structural diagram of the first metal layer or the second metal layer of the circuit board of Fig. 2.

Figs. 6a~6e show diagrams of various patterns of

the double coupling elements of the present invention formed by utilizing a center (center connected) or one-side (N-poles) connection elements.

Figs. 7a~7e show diagrams of patterns of the double coupling elements of the present invention formed by loop type elements.

Fig. 8 shows a diagram of the frequency-selective-surface sub-reflector of the present invention in use.

10 DETAILED DESCRIPTION OF THE INVENTION

[0024] Now please refer to the figures for the explanation of the technical contents and the detailed descriptions of the present invention:

Fig. 1 shows a three-dimensional diagram of the structural appearance of the frequency-selective-surface sub-reflector of the present invention. Fig. 2 shows an exploded view of the structure of the frequency-selective-surface sub-reflector of the present invention. As shown in Fig. 1 and Fig. 2, a frequency-selective-surface sub-reflector 100 of the present invention comprises a circuit board 10, a first outer cover 20 and a second outer cover 30.

[0025] The circuit board 10 includes an insulating layer 12, a first metal layer 14 and a second metal layer 16. The first metal layer 14 and the second metal layer 16 are arranged on two sides of the insulating layer 12. Moreover, a high-low value (namely, a magnitude) of a resonant Q value (a ratio of penetration and reflection) is determined by a thickness of the insulating layer 12. If the thickness of the insulating layer 12 is thicker, the Q value is better, but the disadvantages are that the bandwidth becomes narrow and the loss of penetration increases. Therefore, the present invention utilizes an insulating layer 12 which has a proper thickness to achieve a proper ratio of penetration and reflection, so the Q value will be lower. Generally speaking, a dielectric constant (Dk) of a dielectric material which has dielectric loss (or so-called loss tangent, Df) decreases as the frequency of the electromagnetic wave increases. If the loss tangent value is higher, the dielectric constant is more stable as the working frequency becomes higher. Moreover, if the dielectric constant is higher, the transmission speed of the electromagnetic wave in the medium (the dielectric) is slower. Therefore, in order to increase the penetration rate (the transmission rate) of the electromagnetic wave in the frequency-selective-surface sub-reflector 100 and in order to decrease the loss of the electromagnetic energy at the same time, the present invention uses a dielectric material with a lower dielectric constant and with a low loss tangent value. At the same time, the present invention uses an FR-4 composite material which has a lower cost and is improved to be suitable for high frequency use. The composite material is composited by (namely, comprises) an epoxy resin and a glass fiber cloth. The Dk value of the composite material is about 3.5~4.0. The Df value of the composite material is about 0.005~0.007. However, the Dk value of a general grade

FR-4 composite material is about 4.3~4.8. The Df value of the general grade FR-4 composite material is about 0.016~0.02.

[0026] On the first metal layer 14 and the second metal layer 16, a plurality of double coupling hollow aperture elements 142 and a plurality of double coupling hollow aperture elements 162, are formed by the dry etching or the wet etching process. A metal of the first metal layer 14 is a copper foil. A metal of the second metal layer 16 is a copper foil. In addition to the dependence on the frequency of the electromagnetic waves, the energy loss (insertion loss) of the electromagnetic waves penetrating the frequency-selective-surface sub-reflector 100 is influenced by the surface roughness of the copper foil. If the surface of the copper foil is smoother, the rate of the energy loss is lower. In order to reduce the loss of the electromagnetic waves, the present invention selects copper foils which are suitable for high frequency use and have smoother surfaces ($R_z = 2.0 \pm 0.5 \mu\text{m}$). The first metal layer 14 and the second metal layer 16 are used as two reflecting interface end-planes to form a resonant cavity. In Fig. 1 and Fig. 2, a height (h) of the circuit board 10 is 0.5mm~2.0mm.

[0027] The first outer cover 20 is arranged on a surface of the first metal layer 14 of the circuit board 10. The second outer cover 30 is arranged on the second metal layer 16 of the circuit board 10. The first outer cover 20 and the second outer cover 30 achieve the purposes of avoiding rusting and weatherproof, and the dielectric constant of the selected material is lower (the dielectric constant is close to 1 to be similar with air, and so on) so that the electromagnetic characteristic is not influenced too much by the selected material. In Fig. 1 and Fig. 2, a thickness of the first outer cover 20 is 0.5mm~2.0mm. A thickness of the second outer cover 30 is 0.5mm~2.0mm.

[0028] The circuit board 10, the first outer cover 20 and the second outer cover 30 mentioned above form a high pass filter (a frequency divider) where the high frequency signal passes through the frequency-selective-surface sub-reflector 100, and the low frequency signal is reflected by the frequency-selective-surface sub-reflector 100.

[0029] Fig. 3 shows a partial amplified view of the structural diagram of the first metal layer or the second metal layer of the circuit board of Fig. 2. Fig. 4 shows an equivalent circuit diagram of the double coupling element (the concentric dual rings) of Fig. 3. As shown in Fig. 3 and Fig. 4, on the first metal layer 14 and the second metal layer 16 of the present invention, the first metal layer 14 and the second metal layer 16 respectively include a plurality of double coupling hollow aperture elements 142 and a plurality of double coupling hollow aperture elements 162 which are concentric hollow aperture dual rings. Because the double coupling elements 142 of the first metal layer 14 are the same with the double coupling elements 162 of the second metal layer 16, only the double coupling elements 142 of the first metal layer 14 are illustrated here.

[0030] A double coupling element 142 is, for example

but not limited to, the concentric dual rings which include an inner ring 142a and an outer ring 142b. The concentric dual rings can be circular, quadrate, triangular or polygonal. The double coupling elements 142 form a high pass filter (a frequency divider) through which the high frequency signal passes and by which the low frequency signal is reflected. In order to achieve the feature of high penetrability, the resonant mode has to exist so that signals are coupled from the incoming side direction to the transmission side direction. The present invention requires two penetration frequency bands, K-band ranging from 19.7GHz~20.2GHz and Ka-band ranging from 29.5GHz~30GHz. Therefore, the effects of the dual rings are that each of the two rings has its own corresponding resonance: K-band within 19.7GHz~20.2GHz corresponds to the resonance of the outer ring 142b; Ka-band within 29.5GHz~30GHz corresponds to the resonance of the inner ring 142a. The low frequency band does not have the resonant mode so the low frequency band has low penetration (high reflection). Thus, a high penetration and wideband high pass filter (frequency divider) can be obtained. Because a disk surface of the antenna system is oval (from the view of the incident wave angle, the sectional view is circular), compared to other square structure or cross structure, selecting and using the ring structure which is symmetrical from the view of every reflected wave angles leads to the best efficiency.

[0031] The physical phenomenon displayed by the electromagnetic waves entering the frequency-selective-surface sub-reflector 100 can be approximated by the theory of transmission line. The periodic array slot units on the metal surface of the frequency-selective-surface sub-reflector 100 have band pass features (the low frequency signal is reflected and the high frequency signal penetrates) that can be regarded as an equivalent circuit with capacitor elements C in parallel with inductor elements L. Patch units have band-stop features (the high frequency signal is reflected and the low frequency signal penetrates) that can be regarded as an equivalent circuit with capacitor elements C connected to inductor elements L in series. Therefore, the present invention would like to design the frequency-selective-surface sub-reflector 100 having dual-band band pass features. The design is achieved by selecting each unit to have two different size dimension slot structures. As shown in Fig. 4, "the capacitor element C1 in parallel with the inductor element L1" connected to "the capacitor element C2 in parallel with the inductor element L2" in series is used as the corresponding equivalent circuit. The present invention designs the double coupling element slots (concentric doubled-ring slots). The advantage is that the features of the penetration and reflection of the electromagnetic waves will not change easily as the incident angle and/or the polarization direction change(s). The resonant frequency of the frequency-selective-surface sub-reflector 100 is related to the size dimension of the periodic units. If a radius R1 and a radius R2 for the inner-ring slot T1 and the outer-ring slot T2 are smaller, the capacitor C is

smaller and the resonant frequency is higher. According to the design of the slot size of the double coupling element of the present invention, the outer-ring slot T2 allows a lower resonant frequency, and the inner-ring slot T1 allows a higher resonant frequency. Moreover, there is a coupling M between the outer-ring slot T2 and the inner-ring slot T1, wherein the coupling M can be used as applications of the frequency-selective-surface sub-reflector 100 for different band pass bands. In Fig. 3, a separation of the outer-ring slot T2 of the outer ring 142b is 0.2mm~0.6mm; a radius R2 of the outer ring 142b is 0.9mm~1.5mm; a separation of the inner-ring slot T1 of the inner ring 142a is 0.1mm~0.5mm; the radius R1 of the inner ring 142a is 0.1mm~0.6mm.

[0032] Fig. 5 shows another partial amplified view of the structural diagram of the first metal layer or the second metal layer of the circuit board of Fig. 2. As shown in Fig. 5, a structural periodic arrangement of the double coupling elements 142 and the double coupling elements 162 of the first metal layer 14 and the second metal layer 16 of the present invention is (namely, uses) a hexagonal close packed structure, such as a hexagonal prism arrangement or a honeycomb type structure (arrangement). The advantage of this arrangement is that the uniform sectional area can be displayed/viewed in all cases of the incident angles and the arrangement has the maximum number of and the densest periodic structure elements per unit area (if the number of the periodic structure elements is larger, the displayed features are better).

[0033] Because the maximum working frequency of the frequency-selective-surface sub-reflector 100 of the present invention is about 30 GHz, besides the conditions that "a separation of the outer-ring slot T2 is 0.2mm~0.6mm; a radius R2 is 0.9mm~1.5mm; a separation of the inner-ring slot T1 is 0.1mm~0.5mm; a radius R1 is 0.1mm~0.6mm", the value (designed by the present invention) of a lattice constant P of the frequency-selective-surface sub-reflector 100 is about 3mm~5mm, which can conform to the condition of avoiding generating antenna pattern grating lobes. Moreover, a height h of the circuit board 10 is 0.5mm~2.0mm.

[0034] Figs. 6a~6e show diagrams that various patterns of the double coupling elements of the present invention are formed by utilizing a center (center connected) or one-side (N-poles) connection. Fig. 6a of the present invention discloses a double coupling element which comprises a plurality of straight elements, wherein the straight elements are arranged longitudinally and transversely to form a crisscross pattern, so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0035] Fig. 6b discloses a double coupling element which comprises three legs and utilizes one side of each of the three legs connected together to form a pattern of a three-leg element, wherein angles between each of the three legs are 120 degrees, so that signals are coupled from an incoming side direction to a transmission side

direction to achieve a feature of a high penetrability.

[0036] Fig. 6c discloses a double coupling element which comprises three anchors and utilizes one side of each of the three anchors connected together to form a pattern of a three-anchor element with three arrows pointing outward, wherein angles between each of the three anchors are 120 degrees, so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0037] Fig. 6d discloses a double coupling element which comprises two I-shaped English letters and utilizes centers of the two I-shaped English letters connected crisscross to form a Jerusalem crosses pattern so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0038] Fig. 6e discloses a double coupling element which comprises four L-shaped English letters and utilizes one side of each of the four L-shaped English letters connected together to form a square spiral pattern so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0039] Figs. 7a~7e show diagrams that patterns of the double coupling elements of the present invention are formed by utilizing loop types. Fig. 7a of the present invention discloses a double coupling element which is formed by utilizing a cross loop pattern (namely, comprising a cross loop pattern) so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0040] Fig. 7b discloses a double coupling element which is formed by utilizing a three legged loop pattern (namely, comprising a three legged loop), wherein angles between each legged loop of the three legged loops are 120 degrees so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0041] Fig. 7c discloses a double coupling element which is formed by a circular loop pattern (namely, comprising a circular loop pattern) so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0042] Fig. 7d discloses a double coupling element which is formed by a square loop pattern (namely, comprising a square loop pattern) so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0043] Fig. 7e discloses a double coupling element which is formed by a hexagonal loop pattern (namely, comprising a hexagonal loop pattern) so that signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0044] Fig. 8 shows a diagram that the frequency-selective-surface sub-reflector of the present invention is in use. As shown in Fig. 8, the frequency-selective-surface sub-reflector 100 of the present invention is integrated into an antenna system. The antenna system com-

prises a parabolic main reflector 200, a low frequency receiver (modified LNB) 300 and a high frequency transceiver (modified TRIA) 400. The frequency-selective-surface sub-reflector 100 is combined with and placed between the low frequency receiver 300 and the high frequency transceiver 400, and corresponds to the parabolic main reflector 200. Moreover, the low frequency receiver 300 is an additional Ku-band signal feed and the high frequency transceiver 400 is a K/Ka-band signal feed (TRIA).

[0045] When the antenna system receives satellite television signals, the parabolic main reflector 200 reflects the incident waves of the satellite television signals to the frequency-selective-surface sub-reflector 100. Then, low frequency signals (Ku-band) reflected by the frequency-selective-surface sub-reflector 100 are received by the low frequency receiver 300. High frequency signals (K/Ka-band) penetrate the double coupling elements 142 and the double coupling elements 162 of the frequency-selective-surface sub-reflector 100 so that the (high frequency) signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

[0046] Moreover, in the condition that the first outer cover 20 and the second outer cover 30 of the present invention do not influence electromagnetic wave features of the circuit board 10, the first outer cover 20 and the second outer cover 30 can achieve the purpose of avoiding rusting and the purpose of weatherproof. Therefore, the dielectric constant of a material used in the first outer cover 20 and the second outer cover 30 is selected to be close to 1, similar to air and having less loss, so that the electromagnetic characteristic is not influenced too much. The material can, for example, be a polyethylene foam, an expandable polyethylene, or a low density polyethylene foam and so on. A thickness of the first outer cover 20 is 0.5mm~2mm. A thickness of the second outer cover 30 is 0.5mm~2mm.

Claims

1. A wideband multi-element frequency-selective-surface sub-reflector (100) **characterized in that** the wideband multi-element frequency-selective-surface sub-reflector (100) is with an application to a single offset antenna; the frequency-selective-surface sub-reflector (100) is integrated into an antenna system and is placed between a high frequency transceiver (400) and a low frequency receiver (300); the frequency-selective-surface sub-reflector (100) comprises:

a circuit board (10) comprising an insulating layer (12), a first metal layer (14) and a second metal layer (16), wherein the first metal layer (14) and the second metal layer (16) are placed on two sides of the insulating layer (12), and

respectively comprise a plurality of double coupling hollow aperture elements (142, 162); a first outer cover (20) arranged on a surface of the first metal layer (14) of the circuit board (10) and a second outer cover (30) arranged on the second metal layer (16) of the circuit board (10), wherein the first metal layer (14) and the second metal layer (16) are used as two reflecting interface end-planes to form a resonant cavity; the frequency-selective-surface sub-reflector (100) is configured to reflect a plurality of low frequency signals, and then the low frequency receiver (300) is configured to receive the low frequency signals reflected by the frequency-selective-surface sub-reflector (100); the double coupling hollow aperture elements (142, 162) of the frequency-selective-surface sub-reflector (100) are configured to be penetrated by a plurality of high frequency signals, so that the high frequency signals are coupled from an incoming side direction to a transmission side direction to achieve a feature of a high penetrability.

2. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein the double coupling element hollow aperture (142, 162) is concentric dual rings.
3. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 2, wherein the concentric dual rings comprise an inner ring (142a) and an outer ring (142b).
4. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 3, wherein a separation of an outer-ring slot (T2) of the outer ring (142b) is 0.2mm~0.6mm; a radius (R2) of the outer ring (142b) is 0.9mm~1.5mm; a separation of an inner-ring slot (T1) of the inner ring (142a) is 0.1mm~0.5mm; a radius (R1) of the inner ring (142a) is 0.1mm~0.6mm.
5. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 2, wherein the concentric dual rings are circular, quadrate, triangular or polygonal.
6. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein the insulating layer (12) is a dielectric material that has a low dielectric constant and a low loss tangent value.
7. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein the insulating layer (12) is a composite material comprising an epoxy resin and a glass fiber cloth.
8. The wideband multi-element frequency-selective-

surface sub-reflector (100) in claim 7, wherein a dielectric constant value of the composite material is about 3.5~4.0; a dielectric loss value of the composite material is about 0.005~0.007.

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9. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein a metal of the first metal layer (14) is a copper foil; a metal of the second metal layer (16) is a copper foil.

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10. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein a height of the circuit board (10) is 0.5mm~2.0mm.

11. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein a thickness of the first outer cover (20) is 0.5mm~2mm; a thickness of the second outer cover (30) is 0.5mm~2mm.

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12. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein a structural periodic arrangement of the double coupling hollow aperture elements (142, 162) of the first metal layer (14) and the second metal layer (16) is a hexagonal close packed structure.

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13. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 12, wherein the hexagonal close packed structure is a hexagonal prism arrangement or a honeycomb type structure.

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14. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 13, wherein a value of lattice constant (P) of the frequency-selective-surface sub-reflector (100) is about 3mm~5mm.

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15. The wideband multi-element frequency-selective-surface sub-reflector (100) in claim 1, wherein a dielectric constant of a material used in the first outer cover (20) and the second outer cover (30) is close to 1.

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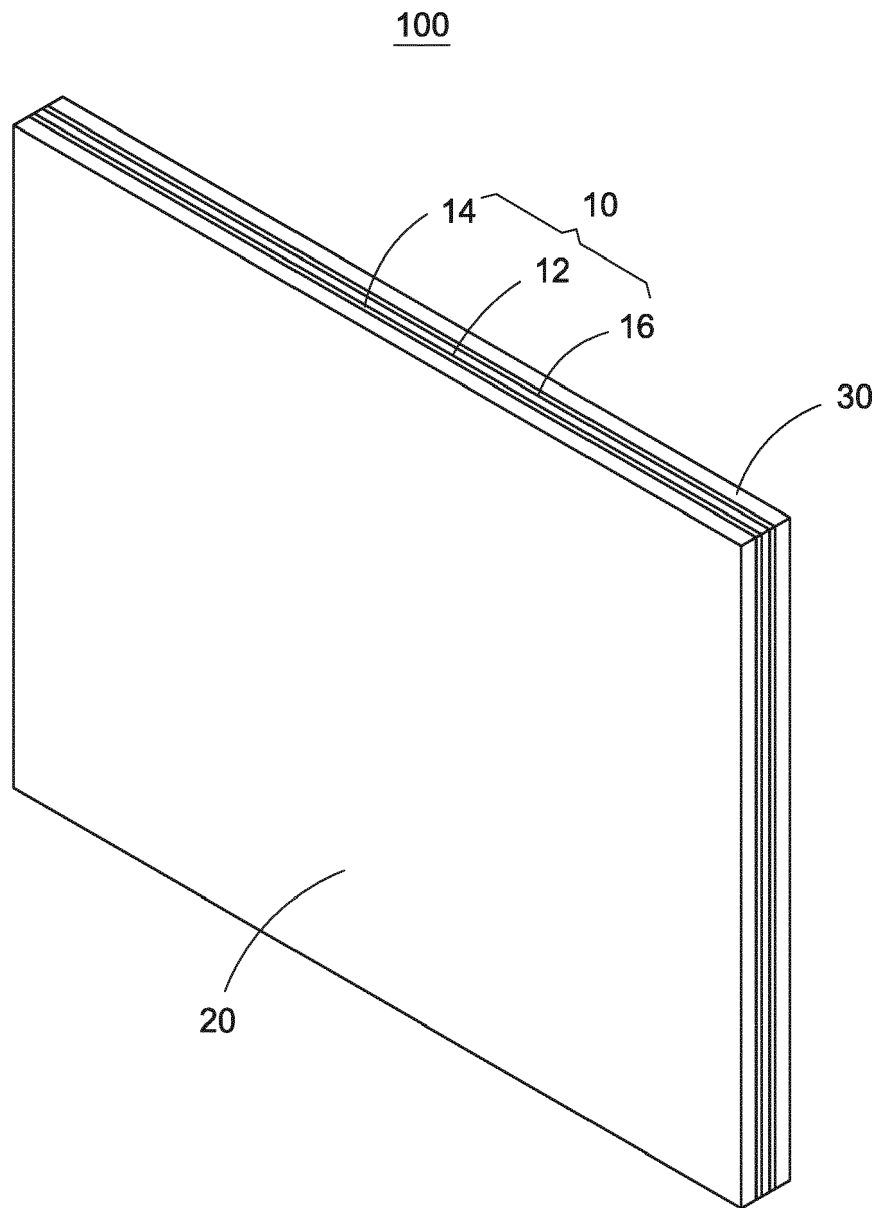


FIG.1

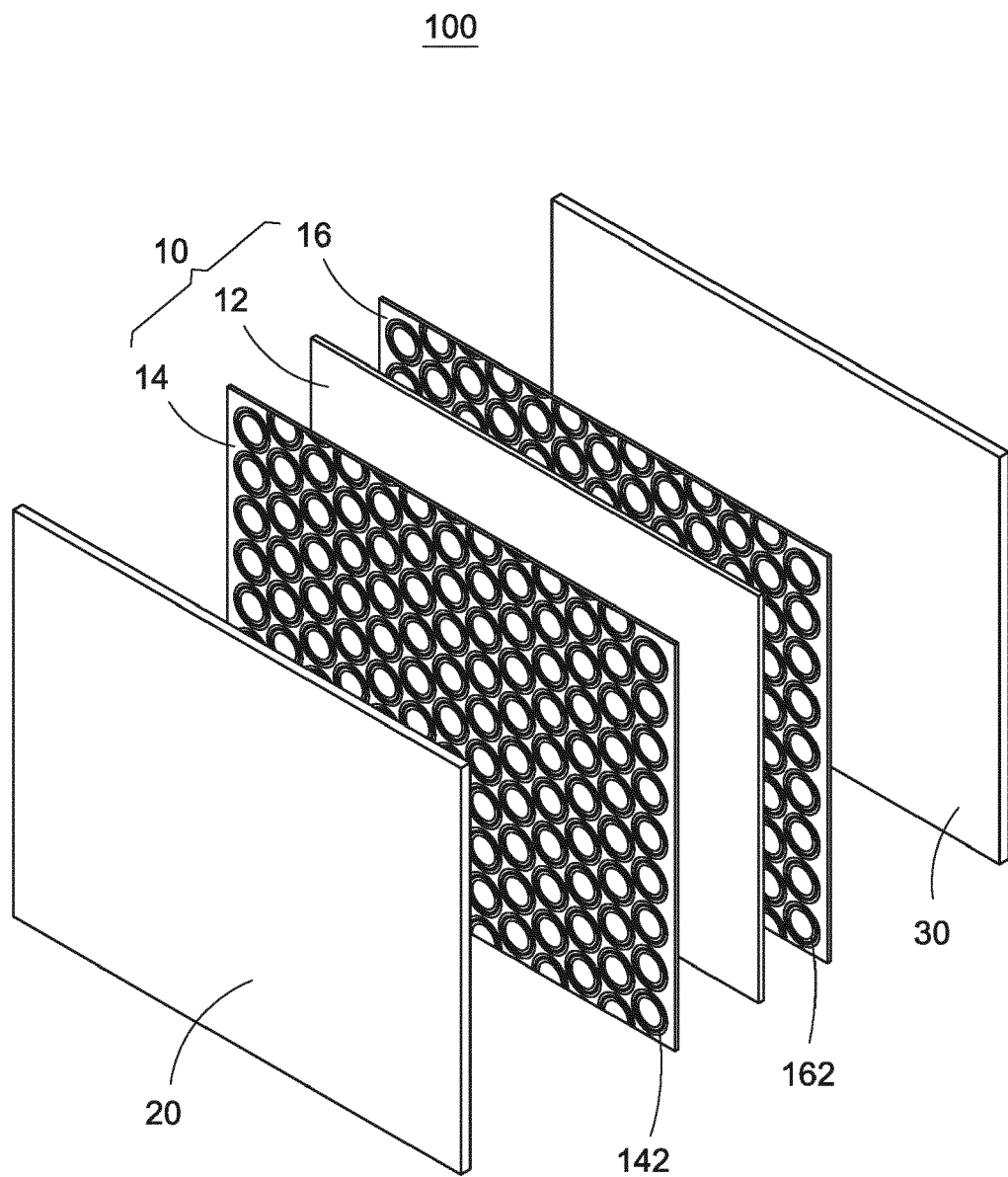


FIG.2

14

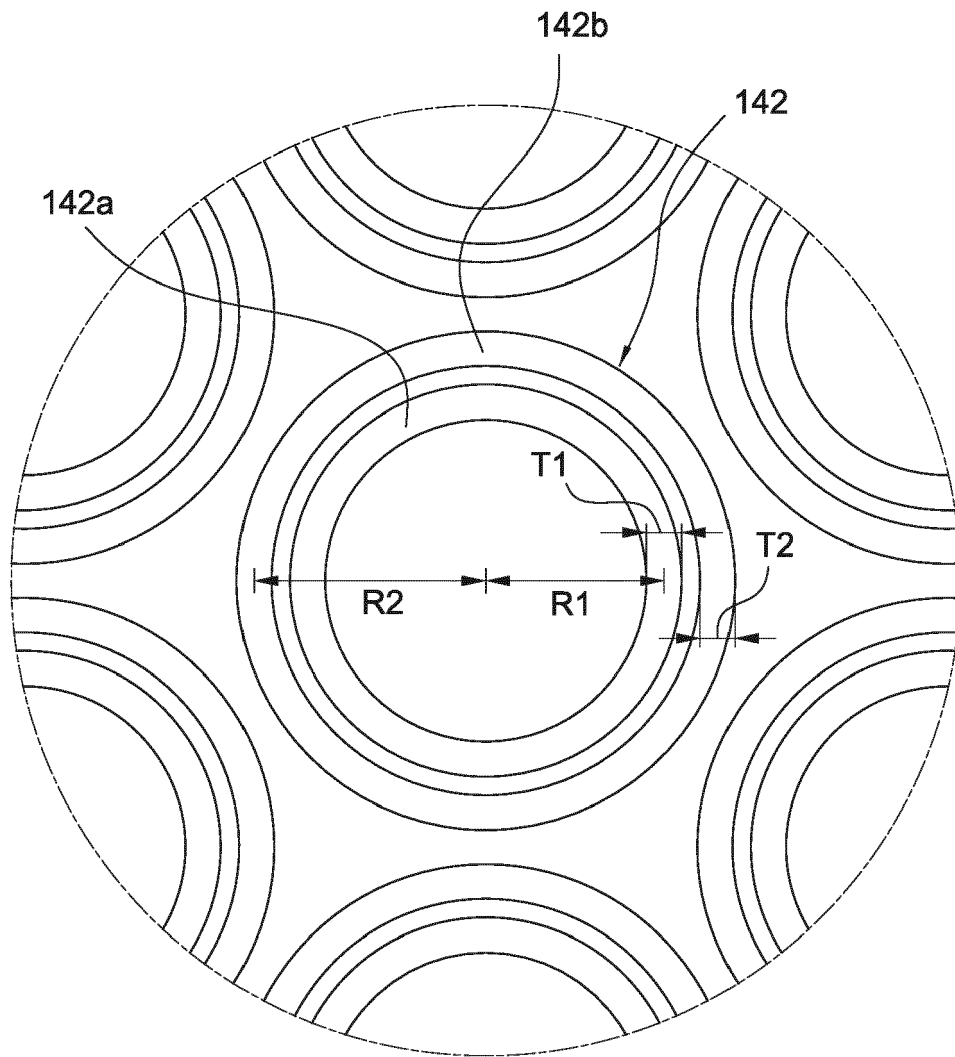


FIG.3

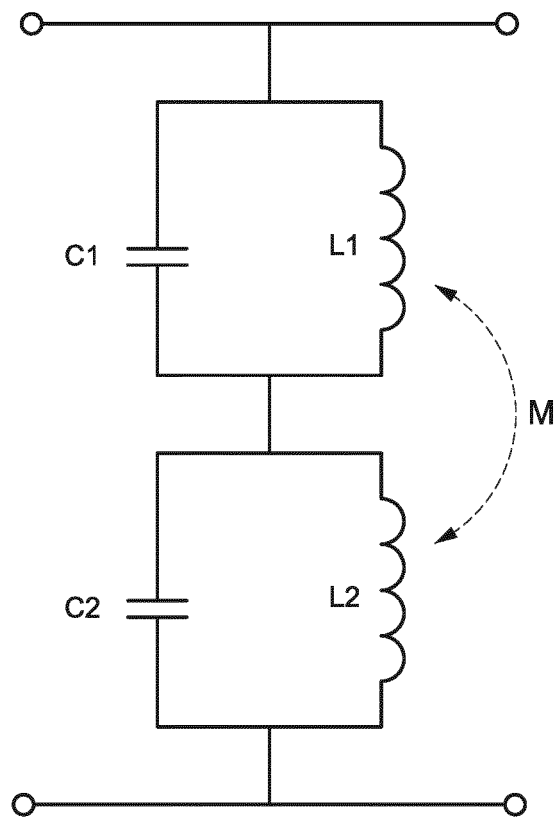


FIG.4

14

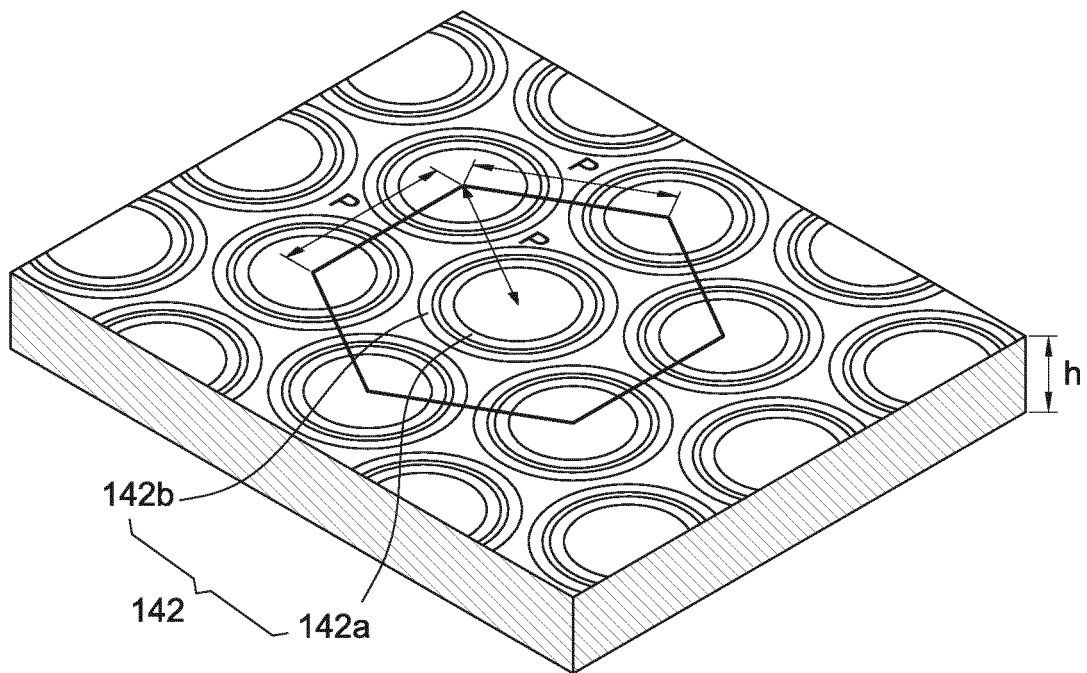


FIG.5

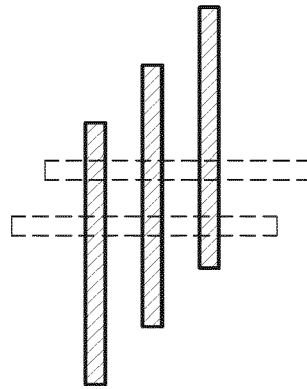


FIG. 6a

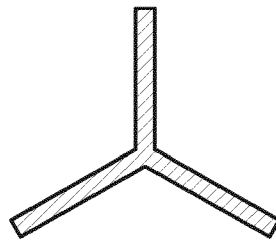


FIG. 6b

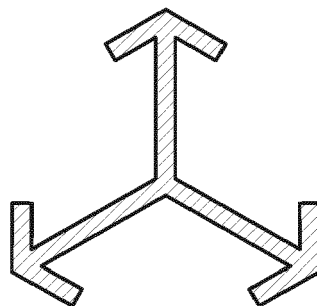


FIG. 6c

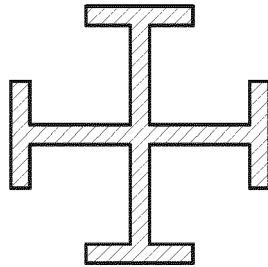


FIG. 6d

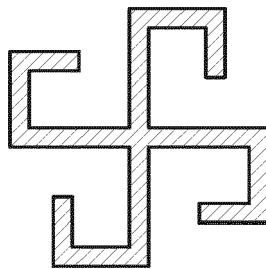


FIG. 6e

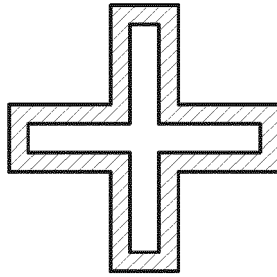


FIG. 7a

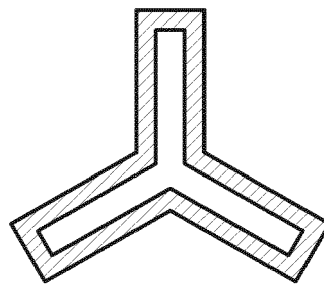


FIG. 7b

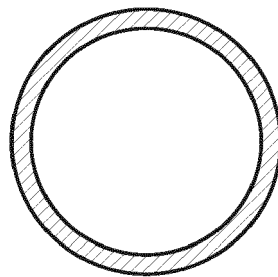


FIG. 7c

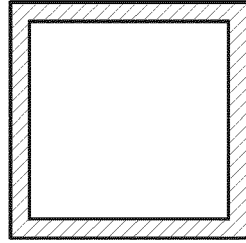


FIG. 7d

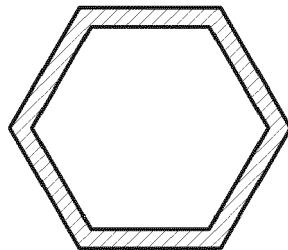


FIG. 7e

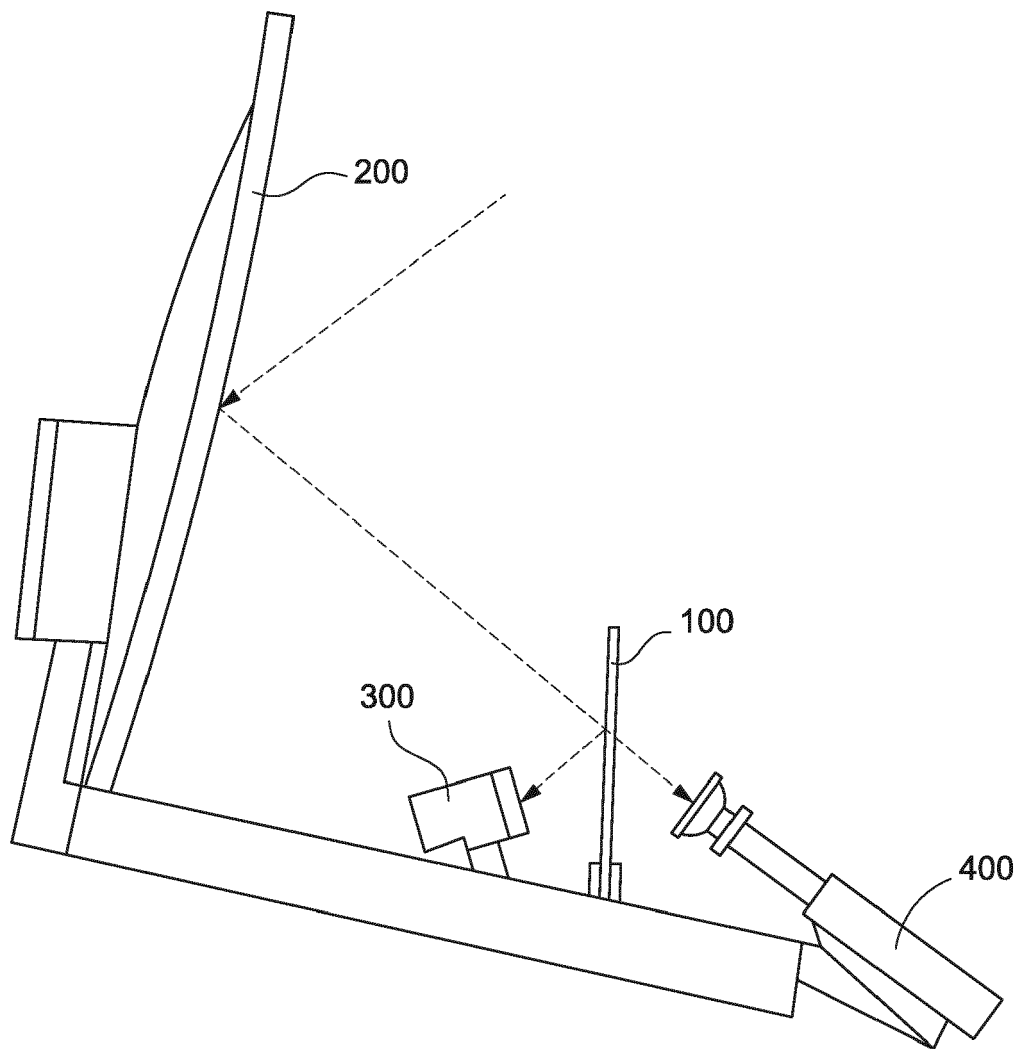


FIG.8



EUROPEAN SEARCH REPORT

Application Number
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Y	US 2003/098818 A1 (WU TE-KAO [US]) 29 May 2003 (2003-05-29) * paragraphs [0024], [0025] * * figure 2 *	1-15	
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Place of search The Hague		Date of completion of the search 28 November 2019	Examiner Taddei, Ruggero
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