(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 4 274 026 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.11.2023 Bulletin 2023/45

(21) Application number: **22734742.4**

(22) Date of filing: **04.01.2022**

(51) International Patent Classification (IPC):
H01Q 21/00 *(2006.01)* ***H01Q 21/08*** *(2006.01)*

(86) International application number:
PCT/CN2022/070029

(87) International publication number:
WO 2022/144017 (07.07.2022 Gazette 2022/27)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **04.01.2021 CN 202110003955**

(71) Applicant: **Shanghai Spaceflight Institute of TT&C And Telecommunication**
Shanghai, 201109 (CN)

(72) Inventors:
- **LUAN, Yinghong**
  Shanghai 201109 (CN)
- **LV, Liqing**
  Shanghai 201109 (CN)
- **LI, Xiuwei**
  Shanghai 201109 (CN)
- **SUN, Yanlong**
  Shanghai 201109 (CN)
- **LIU, Rui**
  Shanghai 201109 (CN)
- **FENG, Jianfeng**
  Shanghai 201109 (CN)
- **LI, Ningjie**
  Shanghai 201109 (CN)
- **LI, Dan**
  Shanghai 201109 (CN)
- **CHEN, Xiong**
  Shanghai 201109 (CN)

(74) Representative: **Argyma**
14 Boulevard de Strasbourg
31000 Toulouse (FR)

(54) ANTI-ALIASING ROTARY DISLOCATION ARRAY ANTENNA

(57) Disclosed is an anti-aliasing rotation dislocation array antenna. A first sub-array, a second sub-array and a third sub-array are in a U-shaped layout, and the second sub-array is parallel to the third sub-array. The first sub-array is perpendicular to the second and the third sub-array, and the first sub-array is arranged at 45° to a positive direction of both x-axis and y-axis of the coordinate system. The fourth sub-array is parallel to the first sub-array. Distances between the units of the fourth sub-array at both ends with the unit of the second and the third sub-array at one end away from the first sub-array are $\frac{\sqrt{2}}{2}\Delta u$. The invention densifies the number of sampling points of the visibility function, increases the detection area without aliasing and improves the system sensitivity.

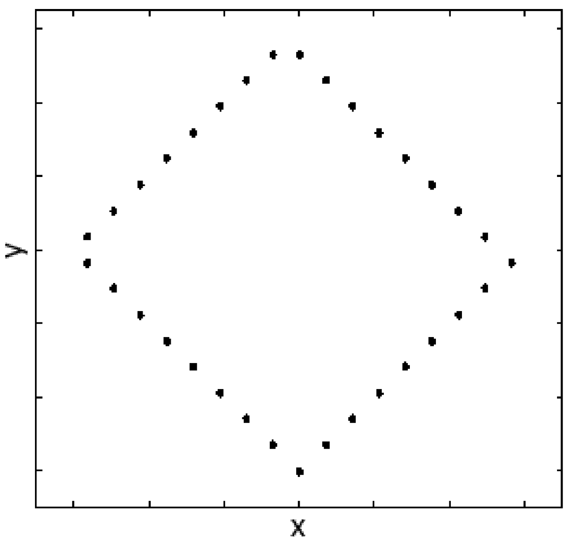

FIG. 1

EP 4 274 026 A1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The invention relates to the field of passive microwave remote sensing under aperture synthesis system, in particular, to an anti-aliasing rotation dislocation array antenna.

Description of the Prior Art

[0002] Aperture synthesis microwave radiation detection, as a passive microwave remote sensing technology that obtains target characteristics by receiving microwave energy radiated from the observed scene, is different from the principle of traditional real-aperture radiation detection that directly performs power measurement and imaging. It obtains the high spatial resolution that cannot be achieved due to the limitations on the size of the real-aperture antenna by using large-aperture antennas for equivalent real-aperture detection of multiple small-unit antennas according to a certain array layout (T-type, Y-type, O-type, etc.). Through the interferometry between every two small-unit antennas, the spatial frequency domain of the radiation brightness temperature distribution in the field of view is sampled to obtain the visibility function, and then the brightness temperature images are reconstructed by performing mathematical operations on the visibility function.

[0003] The array layout has a significant impact on the performance of synthesis aperture radiation detection: the maximum length of the array determines the spatial resolution of the system imaging, the minimum unit spacing of the array determines the alias-free field of view of the system imaging, and the system sensitivity is also closely related to the number of array units and the arrangement of array unit intervals. The performance in sampling the visibility function of different array layouts is different, and the impact on the imaging performance of the system is also different. Therefore, the optimal design of the array layout must comprehensively consider various factors such as system performance indicators (resolution, sensitivity, field of view, etc.) and realizability of the hardware.

SUMMARY OF THE INVENTION

[0004] The technical objective of the invention is to provide an anti-aliasing rotation dislocation array antenna, so as to solve the technical problems of serious aliasing and low sensitivity.

[0005] In order to solve the problems, the invention uses the following technical solutions:

An anti-aliasing rotation dislocation array antenna is provided, the anti-aliasing rotation dislocation array antenna being distributed in a staggered manner based on a coordinate system for determining a spatial position of the anti-aliasing rotation dislocation array antenna, the anti-aliasing rotation dislocation array antenna comprising a first sub-array antenna, a second sub-array antenna, a third sub-array antenna and a fourth sub-array antenna;

the first sub-array antenna comprises N+1 antenna elements arranged at an equal interval Δu in a straight line;

the second sub-array antenna comprises N antenna elements arranged at an equal interval Δu in a straight line;

the third sub-array antenna comprises N antenna elements arranged at an equal interval Δu in a straight line;

the fourth sub-array antenna comprises N antenna elements arranged at an equal interval Δu in a straight line;

wherein the first sub-array antenna, the second sub-array antenna and the third sub-array antenna are in a U-shaped layout, and the second sub-array antenna is parallel to the third sub-array antenna; the first sub-array antenna is perpendicular to the second sub-array antenna and the third sub-array antenna respectively, and the first array antenna is arranged at 45° to a positive direction of an x-axis of the coordinate system and 45° to a positive direction of a y-axis of the coordinate system;

the fourth sub-array antenna is parallel to the first sub-array antenna; distances between the antenna units of the fourth sub-array at both ends of the fourth sub-array antenna and the antenna unit at one end of the second sub-array antenna away from the first sub-array antenna, and between the antenna units of the fourth sub-array antenna at both ends of the fourth sub-array antenna and the antenna unit of the third sub-array antenna at one end of the third sub-array antenna away from the first sub-array antenna are $\frac{\sqrt{2}}{2}\Delta u$.

[0006] Specifically, distances between the antenna units of the second sub-array antenna and the antenna units of the first sub-array antenna close to both ends of the first sub-array antenna and between the antenna units of the third sub-array antenna and the antenna units of the first sub-array antenna close to both ends of the first sub-array antenna are Δu.

[0007] Specifically, a formula for the total number of sample points N_V of a visibility function of the anti-aliasing rotation dislocation array antenna is as follows: $N_v = 8N^2 + 8N + 1$.

[0008] Specifically, a visibility sampling grid pitch of the anti-aliasing rotation dislocation array antenna is

$\frac{\sqrt{2}}{2}\Delta u$, with a minimum unit area of $\Delta s = \frac{\Delta u^2}{2}$.

[0009] Compared with the prior art, the invention has the following advantages and positive effects due to the adoption of the above technical solutions:

Through the reasonable layout of the antenna units, an array antenna is obtained to achieve dislocated sampling of the visibility function, and the anti-aliasing rotation dislocation array antenna is obtained by rotating the array antenna by 45° to achieve dislocated sampling and rotation of the grids, so that the invention densifies the number of sampling points of the visibility function, and increases the detection area without aliasing and improve the detection sensitivity of the system, thereby widening the inversion imaging area and improving the clarity of the inversion image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] By reading the detailed description of the preferred embodiments below, various other advantages and benefits will become clear to those of ordinary skill in the art. The drawings are only used for the purpose of illustrating the preferred embodiments, and are not considered as a limitation to the invention.

Fig. 1 is a view of an array layout of an anti-aliasing rotation dislocation array antenna according to the invention;
Fig. 2 is a view of the sampling of a visibility function corresponding to the array layout based on Fig. 1;
Fig. 3 is a view of a U-shaped array layout;
Fig. 4 is a view of the sampling of a visibility function of a standard rectangular grid corresponding to the array layout based on Fig. 3;
Fig. 5 is a view of a layout of adding a dislocated unit arm in the U-shaped array;
Fig. 6 is a view of the sampling of a visibility function corresponding to the array layout based on Fig. 5;
Fig. 7 is a view of an aliasing-free field of view of the new array layout acquired based on Fig. 1;
Fig. 8 is a view of an aliasing-free field of view of a standard rectangular array acquired based on Fig. 3;
Fig. 9 is an optical image of a certain scene;
Fig. 10 is an inversion image acquired through the array layout of the invention based on Fig. 9;
Fig. 11 is an inversion image acquired through the U-shaped array layout based on Fig. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] In order to more clearly illustrate the embodiments of the invention or the technical solutions in the prior art, the specific implementation manners of the invention will be described below with reference to the accompanying drawings. Obviously, the drawings below are only some examples of the invention, and the ordinary artisans concerned may obtain other drawings on the basis of these drawings without making creative efforts and other embodiments.

[0012] In order to make the drawing concise, each drawing only schematically shows the parts related to the invention, and they do not represent the actual structure of the product. In addition, to make the drawings concise and easy to understand, in some drawings, only one of the components having the same structure or function is schematically shown, or only one of them is marked. Herein, "a" not only means "only one", but also means "more than one".

[0013] An anti-aliasing rotation dislocation array antenna proposed by the invention will be further described in combination with drawings and embodiments. Advantages and features of the invention will be apparent from the following description and claims.

Embodiment 1

[0014] As shown in Fig. 1 and Fig.2, the embodiment provides an anti-aliasing rotation dislocation array antenna, and how it is obtained will now be described in detail.

[0015] As shown in Fig. 3, in the embodiment, first, several antenna units need to be placed in a coordinate system according to a U-shaped layout array, wherein the coordinate system is only for intuitively viewing the positional relationship of the antenna units, and has nothing to do with practical applications. The spacing 1 in the coordinate system represents $1^*\Delta u$. Specifically, the spacing between several adjacent antenna units is Δu, the U-shaped array includes three sides composed of antenna units, and each side is a straight line and two adjacent sides are perpendicular to each other. The U-shaped array is now divided into a first sub-array antenna, a second sub-array antenna and a third sub-array antenna, wherein the first sub-array antenna is a bottom side of the U-shaped array and includes N+1 antenna units, and the second sub-array antenna and the third sub-array antenna both include N antenna units, N being a positive integer. As shown in Fig. 3, combined with the coordinate system, x-coordinates of the antenna units of the second sub-array antenna are consistent and both are 0, and x-coordinates of the antenna units of the third sub-array antenna are consistent and both are 8. Based on the above U-shaped array layout, sampling of a standard rectangular grid is formed, a view of the sampling of the visibility function of the standard rectangular grid is shown in Fig. 4. A sampling spacing of the standard rectangular grid is Δu, a minimum unit area $\Delta s = \Delta u^2$ of a sampling plane of the visibility function is $\Delta s = \Delta u^2$, with the total number of sample points of $N_{v1} = 4N^2 + 4N + 1$.

[0016] Next, as shown in Fig. 5, in the embodiment, the fourth sub-array antenna is added at an opening in the above U-shaped array layout; the number of the antenna units of the fourth sub-array antenna is *N,* the antenna units are arranged in a straight line with the spacing of Δu, and the fourth sub-array antenna is perpendicular to the first sub-array antenna. Combined with the coordinate system, coordinates of the antenna units at both ends of the fourth sub-array antenna are (0.5, 8.5), (7.5, 8.5) respectively, i.e., a distance between antenna units at both ends of the fourth sub-array antenna and the antenna unit of the nearest second sub-array antenna, and between the antenna units at both ends of the fourth sub-array antenna and the antenna unit of the third sub-array antenna is $\frac{\sqrt{2}}{2}\Delta u$. A dislocated grid sampling is formed by this arrangement, with a view of sampling of the visibility function shown in Fig. 6; the total number of samples of the visibility function is $N_{v2} = 8N^2 + 8N + 1$.

[0017] As shown in Fig. 1, finally, combined with the coordinate system, with the coordinate point (0, 0) as an origin of rotation, the above antenna units in the first sub-array antenna, the second sub-array antenna, the third sub-array antenna and the fourth sub-array antenna are rotated counterclockwise by 45°, then the anti-aliasing rotation dislocation array antenna of the embodiment is obtained. The rotation dislocated grid sampling is formed by this arrangement, with a specific view of sampling of the visibility function shown in Fig. 6; a sampling spacing of the visibility function is $\frac{\sqrt{2}}{2}\Delta u$, and the minimum unit area is $\Delta s = \frac{\Delta u^2}{2}$, with the total number of sample points of $N_{v3} = N_{v2} = 8N^2 + 8N + 1$.

[0018] The anti-aliasing capabilities of the U-shaped array layout and the array layout of the embodiment are now compared. According to the relationship between the synthesis aperture sampling interval Δl and the aliasing-free field of view, if a range of the aliasing-free field of view is $|\xi_{min}, \xi_{max}|$, a condition for aliasing-free in the field of view is $\Delta l \leq \frac{1}{\xi_{max}-\xi_{min}}$, i.e., the smaller the sampling interval, the larger the range of aliasing-free. An interval of the U-shaped array layout is Δu, with corresponding aliasing-free field of view shown in Fig. 8; an interval of the rotation dislocation array layout of the embodiment is $\frac{\sqrt{2}}{2}\Delta u$, with corresponding aliasing-free field of view shown in Fig. 7; by comparison, the range of aliasing-free field of view is expanded by $\sqrt{2}$ times.

[0019] As shown in Figs. 9 to 11, in order to further illustrate the performance of the embodiment, the clarities of the inversion for the images of the same scene performed by the embodiment and the U-shaped array layout are described. In the field of microwave remote sensing, sensitivity is an important index to measure the effect of remote sensing, which reflects the minimum detectable degree of brightness temperature changes of each pixel in the image, and is expressed as the clarity of the inverted images, thereby providing beneficial help for subsequent extraction of required information from images. According to the relationship formula $\Delta T \propto \Delta s\sqrt{N_v}$ between the sensitivity of synthesis aperture and the array layout, the sensitivity ΔT is proportional to the product of the square root $\sqrt{N_v}$ of the minimum unit area Δs of the visibility sampling plane and the number of sample points of the visibility function. In the U-shaped array layout, the minimum unit area is $\Delta s = \Delta u^2$, and the total number of sample points is $N_{v1} = 4N^2 + 4N + 1$; in the embodiment, the minimum unit area is $\Delta s = \frac{\Delta u^2}{2}$, and the total number of sample points is $N_{v3} = 8N^2 + 8N + 1$; by comparison and calculation, the sensitivity of the array layout of the embodiment is $\sqrt{2}$ times higher than that of the U-shaped array layout; the smaller the sensitivity value is, the more sensitive it is. MATLAB software is used for inversion simulation. Fig. 9 is the optical image of the scene, Fig. 11 is the inversion image of the U-shaped array layout using inverse Fourier transform, and Fig. 10 is an inversion image based on the array layout of the embodiment using inverse Fourier transform. It can be seen that the inversion image based on the new layout of the embodiment reflects more detailed information, the outline is clearer, and the performance is better.

[0020] As a supplementary note, if the alias-free field of view required by the system detection is certain, in the dislocation layout corresponding to the embodiment, the spacing between antenna units is $\sqrt{2}$ times that of the U-shaped layout. Under the condition that the spatial resolution (i.e., the maximum length of the sampling plane of the visibility function) remains unchanged, the new layout may greatly reduce the number of units, and reduce the design and engineering requirements for unit antennas.

[0021] The implementations of the present invention are described in detail above with reference to the accompanying drawings, but the present invention is not limited to the above implementations. Even if various changes are made to the invention, if these changes fall within the scope of the claims of the invention and equivalent technologies, they still fall within the protection scope of the invention.

Claims

1. An anti-aliasing rotation dislocation array antenna, the anti-aliasing rotation dislocation array antenna being distributed in a staggered manner based on a coordinate system for determining a spatial position of the anti-aliasing rotation dislocation array antenna, the anti-aliasing rotation dislocation array antenna comprising a first sub-array antenna, a second sub-array antenna, a third sub-array antenna, and a fourth sub-array antenna;

   the first sub-array antenna comprises N+1 antenna units arranged at an equal interval Δu in a straight line, N being a positive integer;
   the second sub-array antenna comprises N antenna units arranged at an equal interval Δu in a straight line;
   the third sub-array antenna comprises N antenna units arranged at an equal interval Δu in a straight line;
   the fourth sub-array antenna comprises N antenna units arranged at an equal interval Δu in a straight line;
   wherein the first sub-array antenna, the second sub-array antenna, and the third sub-array antenna are in a U-shaped layout, and the second sub-array antenna is parallel to the third sub-array antenna; the first sub-array antenna is perpendicular to the second sub-array antenna and the third sub-array antenna respectively, and the first array antenna is arranged at 45° to a positive direction of an x-axis of the coordinate system and 45° to a positive direction of a y-axis of the coordinate system;
   the fourth sub-array antenna is parallel to the first sub-array antenna; distances between the antenna units of the fourth sub-array at both ends of the fourth sub-array antenna and the antenna unit of the second sub-array antenna at one end of the second sub-array antenna away from the first sub-array antenna, and between the antenna units of the fourth sub-array antenna at both ends of the fourth sub-array antenna and the antenna unit of the third sub-array antenna at one end of the third sub-array antenna away from the first sub-array antenna are $\frac{\sqrt{2}}{2}\Delta u$.

2. The anti-aliasing rotation dislocation array antenna according to claim 1, wherein distances between the antenna units of the second sub-array antenna and the antenna units of the first sub-array antenna close to both ends of the first sub-array antenna and between the antenna units of the third sub-array antenna and the antenna units of the first sub-array antenna close to both ends of the first sub-array antenna are Δu.

3. The anti-aliasing rotation dislocation array antenna according to claim 1, wherein a formula for the total number of sample points N_V of a visibility function of the array layout is as follows: $N_v = 8N^2 + 8N + 1$.

4. The anti-aliasing rotation dislocation array antenna according to claim 1, wherein a visibility sampling grid pitch of the anti-aliasing rotation dislocation array antenna is $\frac{\sqrt{2}}{2}\Delta u$, with a minimum unit area of $\Delta s = \frac{\Delta u^2}{2}$.

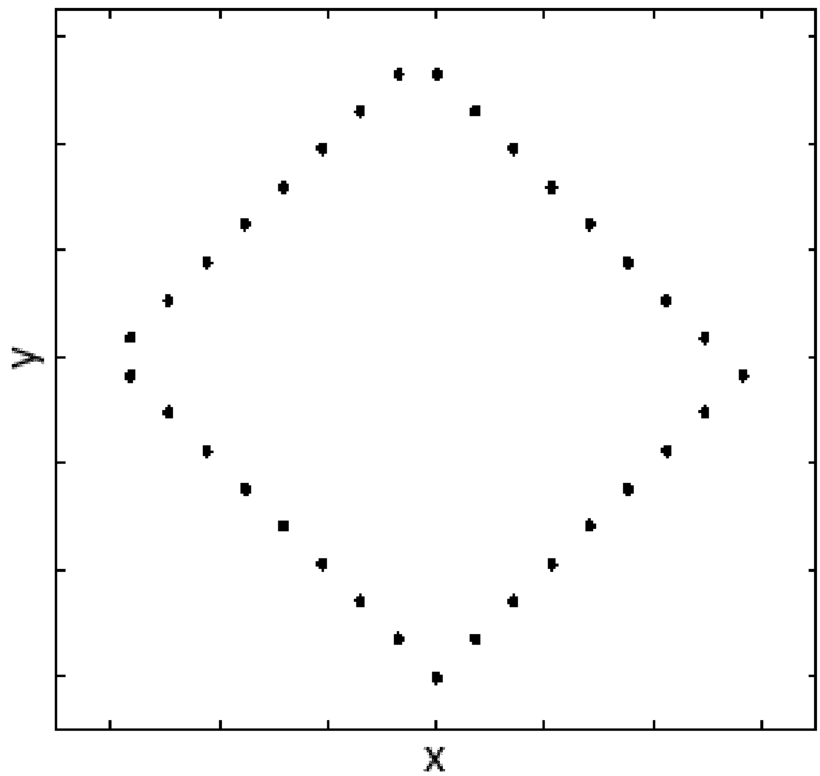

FIG. 1

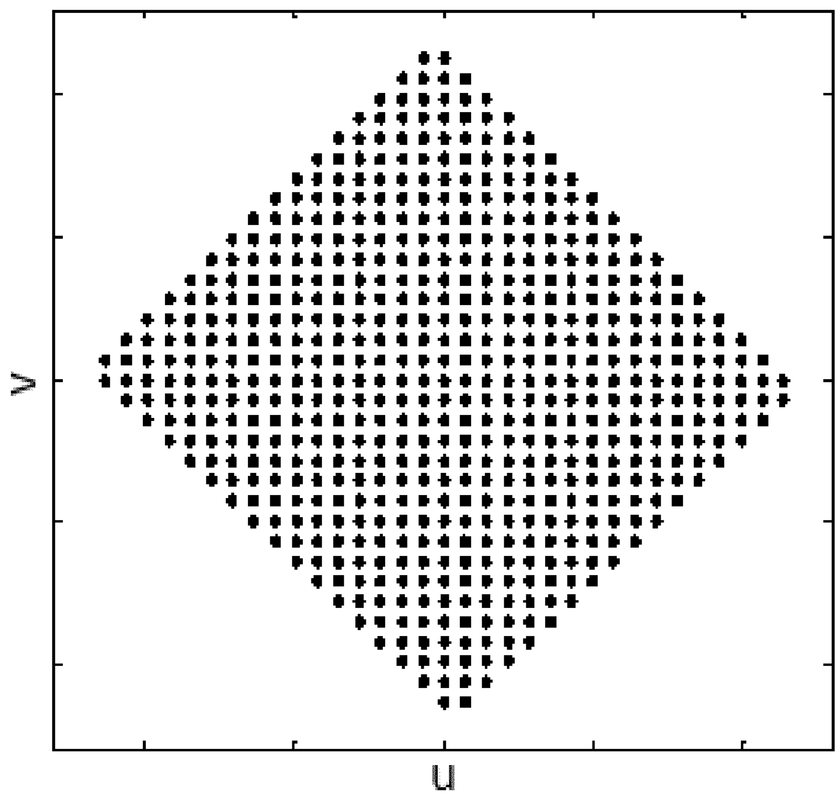

FIG. 2

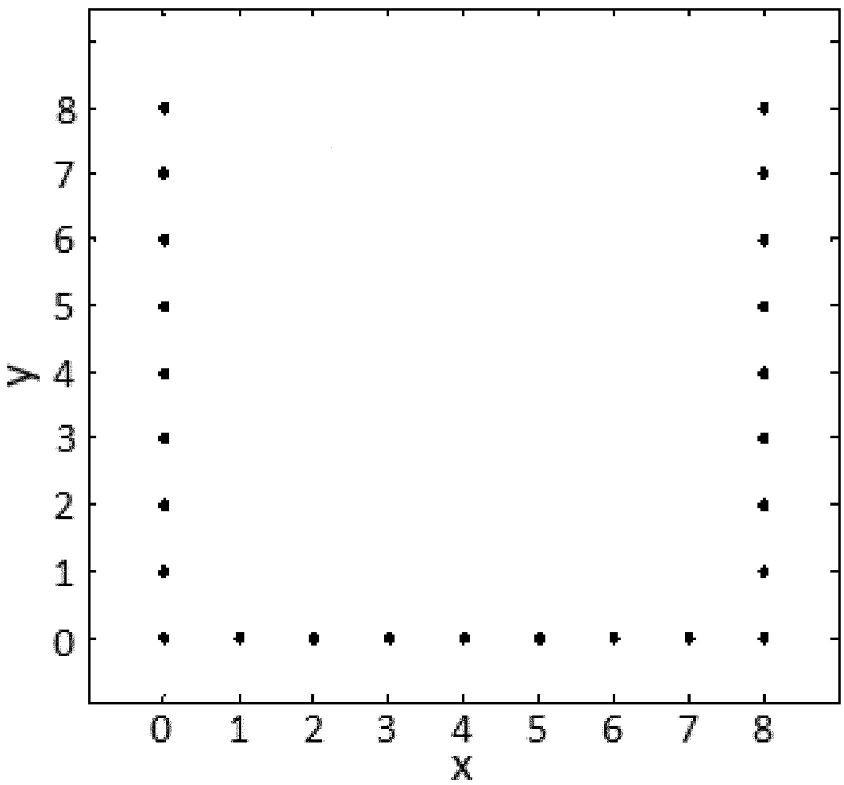

FIG. 3

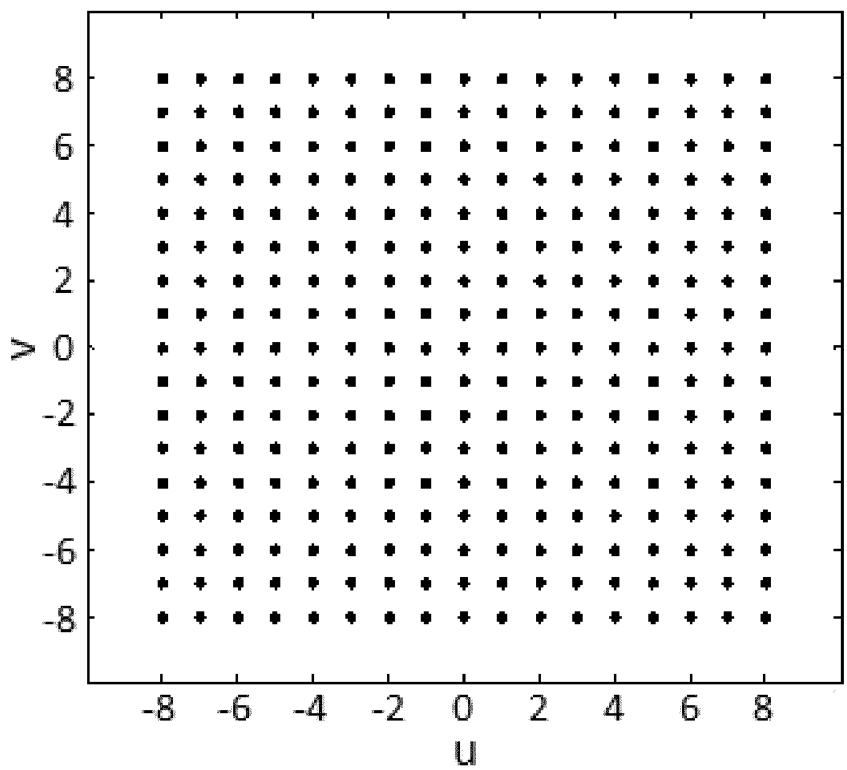

FIG. 4

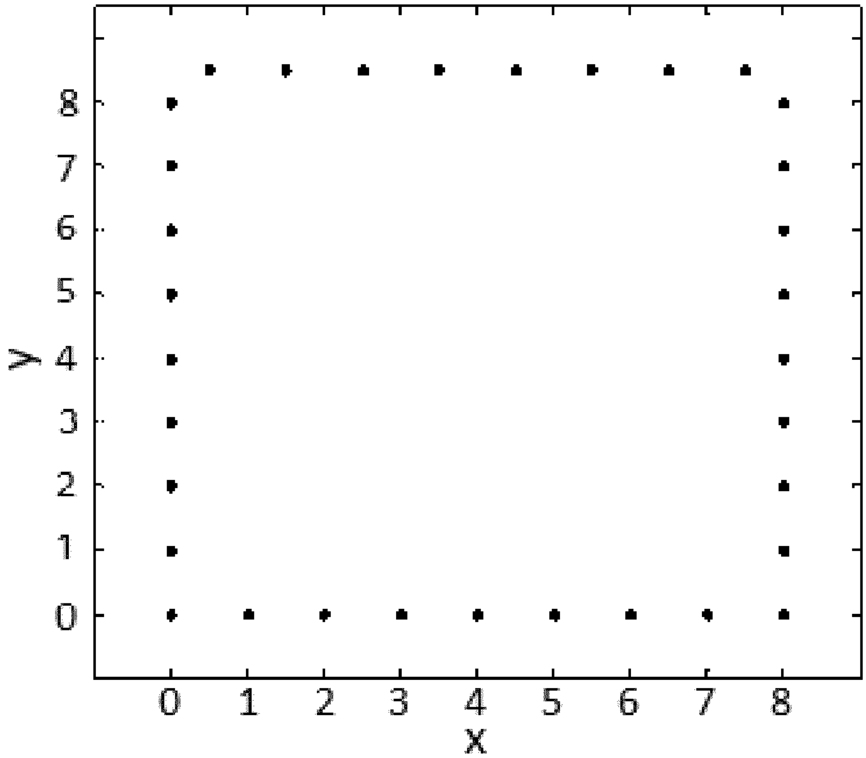

FIG. 5

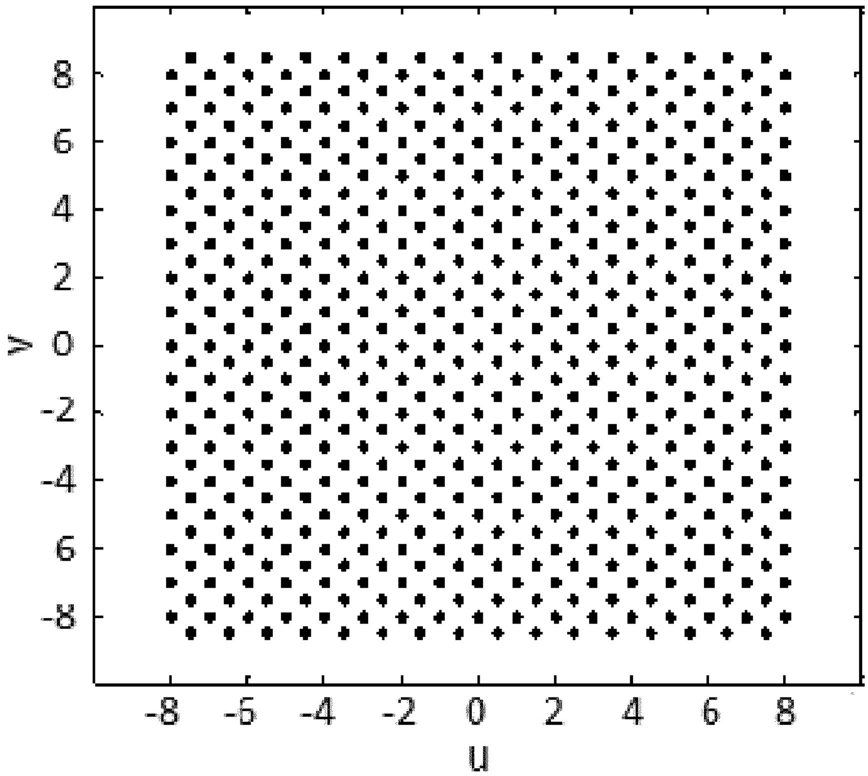

FIG. 6

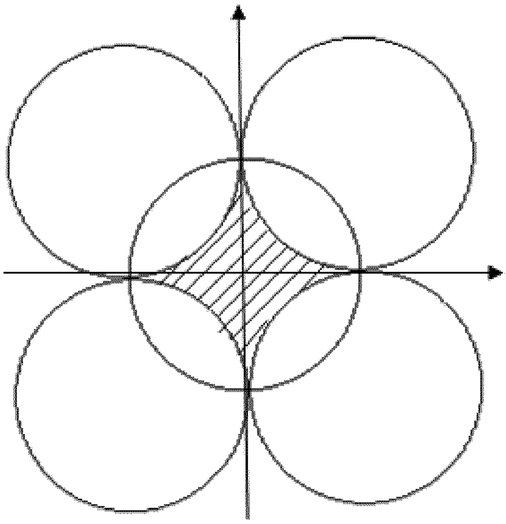

FIG. 7

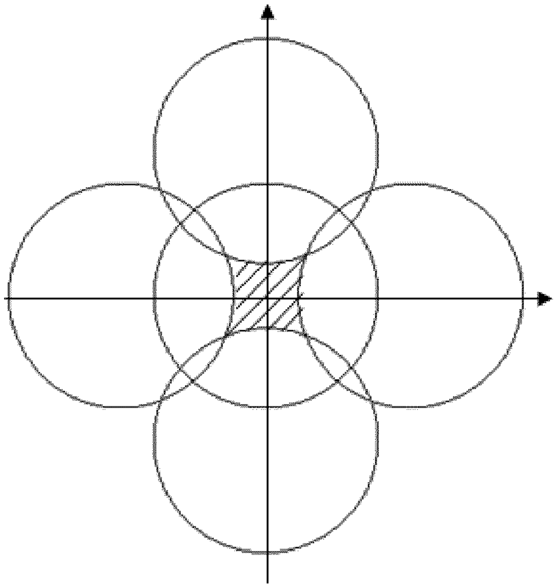

FIG. 8

FIG. 9

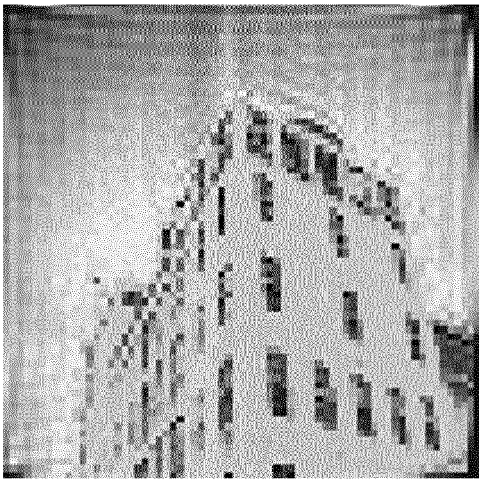

FIG. 10

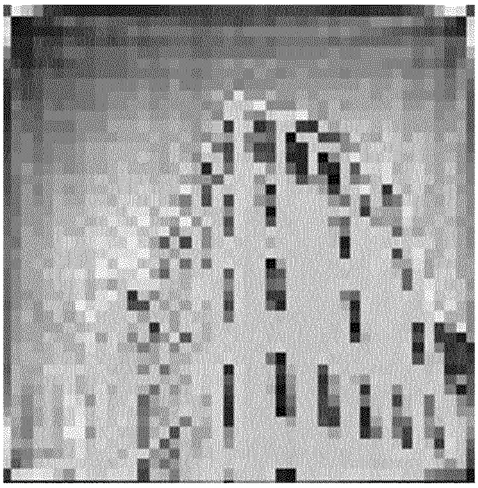

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/070029

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 21/00(2006.01)i；H01Q 21/08(2006.01)i

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)

CNKI, CNPAT, EPODOC, WPI, IEEE: 阵列, 遥测, 检测, 遥感, 综合, 孔径, 旋转, 转动, 成像, 图像, 分辨率, U型, antenna, remote sens+, detect, synthesis, aperture, rotat+, imag+, resolution

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 112768955 A (SHANGHAI SPACEFLIGHT TT&C AND TELECOMMUNICATION INSTITUTE) 07 May 2021 (2021-05-07) claims 1-4	1-4
A	CN 101975947 A (HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY) 16 February 2011 (2011-02-16) description paragraphs [0022]-[0079], figure 3	1-4
A	CN 110662982 A (ARBE ROBOTICS LTD.) 07 January 2020 (2020-01-07) entire document	1-4
A	CN 104808201 A (THE 41ST INSTITUTE OF CHINA ELECTRONICS TECHNOLOGY GROUP CORPORATION) 29 July 2015 (2015-07-29) entire document	1-4
A	CN 209342935 U (TSINGHUA UNIVERSITY et al.) 03 September 2019 (2019-09-03) entire document	1-4
A	US 2014091965 A1 (BATTELLE MEMORIAL INSTITUTE) 03 April 2014 (2014-04-03) entire document	1-4

☐ Further documents are listed in the continuation of Box C. ☑ 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
17 March 2022	**31 March 2022**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China** Facsimile No. **(86-10)62019451**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/070029

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	112768955	A	07 May 2021	None			
CN	101975947	A	16 February 2011	None			
CN	110662982	A	07 January 2020	US	2020003884	A1	02 January 2020
				EP	3577490	A1	11 December 2019
				WO	2018142396	A1	09 August 2018
CN	104808201	A	29 July 2015	None			
CN	209342935	U	03 September 2019	None			
US	2014091965	A1	03 April 2014	EP	2898569	A2	29 July 2015
				WO	2014058512	A2	17 April 2014
				CA	2883082	A1	17 April 2014
				AU	2013330383	A1	19 March 2015

Form PCT/ISA/210 (patent family annex) (January 2015)