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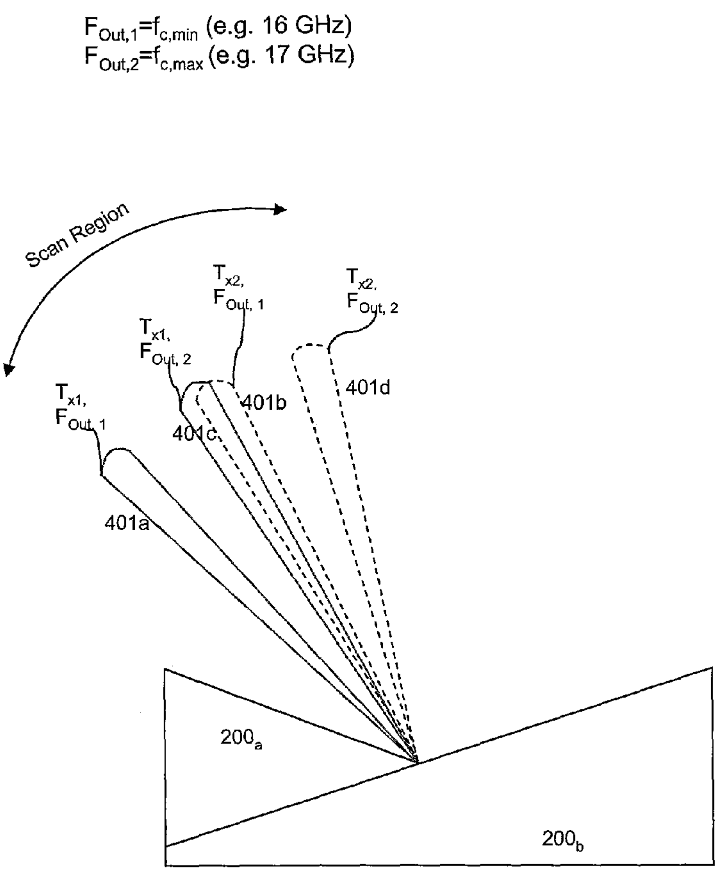
(54) Title: FREQUENCY SCANNING ANTENNA



(57) Abstract: Embodiments of the invention are concerned with frequency scanning antennas for transceiving radio frequency energy for use in detecting and monitoring ground-based targets. In one arrangement the frequency scanning antenna is embodied as a structure that is capable of steering a radio frequency beam to a plurality of different angles about the antenna structure: the antenna structure comprises at least two array antennas and a controller for controlling input of energy to the two array antennas, and the array antennas are disposed within the antenna structure such that the antenna structure is capable of steering a beam to a first angle using one of said two array antennas and of steering a beam to a second angle, different to said first angle, using the other of said two array antennas. Thus in embodiments of the invention two or more array antennas are arranged to form an antenna structure, and the feed to a respective antenna array of the antenna structure is coordinated so that individual scan areas can be combined to generate an increased overall scan region.

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Frequency Scanning Antenna

Field of the Invention

The present invention relates to a frequency scanning antenna, and relates specifically to frequency scanning antennas that are particularly, but not exclusively, suitable for use in detecting and monitoring ground-based targets.

Background of the Invention

Frequency scanning antennas are used in radar systems in order to scan across a given region for the presence of objects. As is known, such frequency scanning arrays can steer a beam in an angular plane in response to input signals of varying frequencies. Particular examples of frequency scanning arrays include the serpentine waveguide, as described in United States patent number US4868574 and the travelling wave wire antenna, as described in United States patent number US3290688.

Alternative mechanisms for steering a beam include mechanical devices comprising an antenna that physically moves in space, or phased antenna arrays that are arranged to steer radiation as it is transmitted or received. A problem with the mechanical radar systems is that their operation is reliant on physical components and associated control and moving parts. This inventory of parts is costly and can require a commensurately large power source.

One known group of electronic devices is phased antenna arrays, which apply various phase shifts to signals, thereby effectively steering the received and transmitted beams. These electronic devices are commonly used in RF sensor and communications systems because they do not involve physical motion of the antenna and are capable of moving a beam rapidly from one position to the next. Whilst radar systems incorporating such devices can provide an extremely accurate measure of the position of targets, a problem with these types of electronic devices is that adequate control of the beam requires often several arrays of electronics components; this increases the physical size, complexity and cost of the radar system.

Frequency scanning arrays have been combined with moving parts that rotate in another plane, as described in US patent US4868574. However, a problem with this combination is that it incurs the size and cost shortcomings of regular mechanical scanning system and performance-wise, is less accurate than the phased antenna systems.

Summary of the Invention

In relation to the frequency scanning antenna, a particularly efficient antenna (in terms of level of complexity - relatively low - and performance - relatively good) is the travelling wave antenna. Application of such a travelling wave antenna is described in US5765098, which describes a single antenna array for transmitting, and a single antenna array for receiving, signals in a satellite system. However, a problem with this type of antenna is that it only radiates over a relatively narrow scan angle as the frequency is changed, this limiting the scan area over which the antenna can be used; such a single antenna array is of course perfectly acceptable for applications such as satellite systems in view of the high altitude, since a relatively modest scan angle translates to a significant angular extent at the point of receipt by the satellites.

According to an aspect of the invention, the inventors have developed a frequency scanning antenna structure for transceiving radio frequency energy and being capable of steering a radio frequency beam to a plurality of different angles about the antenna structure, the antenna structure comprising at least two array antennas and a controller for controlling input of energy to the two array antennas, wherein the array antennas are disposed within the antenna structure such that the antenna structure is capable of steering a beam to a first angle using one of said two array antennas and of steering a beam to a second angle, different to said first angle, using the other of said two array antennas.

Thus in embodiments of the invention two or more array antennas are arranged to form an antenna structure, and the feed to a respective antenna array of the antenna structure is coordinated so that individual scan areas can be combined to generate an increased overall scan region. In one arrangement the antenna structure is arranged to steer a beam across a plurality of non-contiguous angular regions, and in another to steer a beam across a contiguous angular region. Conveniently the antenna structure is capable of steering a beam across a first range of angles (a first angular region) using one of said two array antennas and of steering a beam across a second range of angles (second angular region) using the other of said two array antennas: the first and second angular regions being different, and collectively offering a scan region of an angular extent greater than that achievable with individual antenna arrays.

Conveniently each said array antenna comprises input means for inputting said energy thereto, and the controller is arranged to input energy to respective array antennas so as to steer the beam to said first and second angles. More specifically, each input means is arranged to input energy to respective array antennas so as to steer the beam across said contiguous or non-contiguous angular regions. In one arrangement the input means is connectable to ends of the antenna array and is in operative association with a frequency generator – such as that described above – so as to receive signals comprising radio frequency energy at a plurality of different frequencies in order to steer the beam.

Preferably the controller is arranged to input energy in accordance with a predetermined sequence so as to steer the beam across said first and second angles, the sequence comprising, for example, inputting energy to a first end of the first antenna array, inputting energy to a first end of the second antenna array, inputting energy to a second end of the second antenna array, and inputting energy to a second end of the second antenna array.

In relation to the configuration of the antenna structure itself, the antenna structure can conveniently be characterised in terms of a longitudinal axis and a transverse axis perpendicular to said longitudinal axis: a first of said array antennas being inclined at said first angle relative to said transverse axis and a second of said array antennas being inclined at said second angle relative to said transverse axis. Moreover, the first and second array antennas are symmetrically disposed about the longitudinal axis and each of said array antennas comprises two ends and two side portions. In one arrangement a side portion of said second array antenna substantially abuts a side portion of said first array antenna, while in another arrangement an end portion of the second array antenna substantially abuts that of the first array antenna. The extent of the scan region is dependent on the physical relationship between the two array antennas, more specifically on the angle each respective array antenna makes to the transverse axis. In one arrangement the angular extent of the radar system is substantially 80 degrees, but other angles are possible, ranging from 60 degrees, 100 degrees, 120 degrees, consistent with various arrangements of the antenna arrays within the antenna structure. Furthermore the antenna structure can be configured so as to include more than two array antennas, thereby further increasing the angular extent of the radar system.

In one arrangement, each of the array antennas comprises a mesh structure and a dielectric base. Each mesh structure can comprise a plurality of interconnected elements embodied as a micro circuit strip (commonly called a microstrip) and can conveniently be disposed on a surface of a corresponding said dielectric base, which in turn is supported by a ground plane.

The mesh structure can conveniently be characterised by the lengths of respective sides and ends of the elements: each of said elements comprising two sides and two ends of respective lengths, the length of said sides being greater than the length of said ends. Typically the length of the sides is of the order of one wavelength at a mid-point between said first frequency and said second frequency and the length of the ends is of the order of one-half of one wavelength at said mid-point frequency. Each mesh element has a characteristic width, and in a preferred arrangement the mesh widths of the sides are progressively decreased from the centre of the mesh to each respective end thereof. Since impedance is inversely proportional to mesh width, it will be appreciated that this provides a convenient means of controlling the impedance of the antenna array elements and thus the resulting radiation pattern.

Further features and advantages of the invention will become apparent from the following description of preferred embodiments of the invention, given by way of example only, which is made with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a schematic block diagram showing components of a radar system according to embodiments of the invention;

Figure 2a is a schematic diagram showing an embodiment of an antenna array utilised in the antenna shown in Figure 1;

Figure 2b is a schematic diagram showing another embodiment of an antenna array utilised in the antenna shown in Figure 1;

Figure 3 is a schematic engineering drawing showing an antenna structure comprising the antenna array of Figure 2a use in the radar system shown in Figure 1;

Figure 4a is a schematic diagram showing radiation emitted from the antenna structure of Figure 3 for a given output frequency;

Figure 4b is a schematic diagram showing radiation emitted from the antenna structure of Figure 3 for a given output frequency;

Figure 5 is a schematic engineering drawing showing an antenna structure comprising the antenna array of Figure 2b for use in the radar system shown in Figure 1;

Figure 6 is a schematic diagram showing radiation emitted from the antenna structure of Figure 5;

Figure 7 is a schematic block diagram showing components of a radar system according to a yet different embodiment of the invention; and

Figure 8 is a schematic engineering drawing showing an alternative antenna structure comprising the antenna arrays of Figure 2a or 2b for use in the radar system shown in Figure 1.

Several parts and components of the invention appear in more than one Figure; for the sake of clarity the same reference numeral will be used to refer to the same part and component in all of the Figures. In addition, certain parts are referenced by means of a number and one or more suffixes, indicating that the part comprises a sequence of elements (each suffix indicating an individual element in the sequence). For clarity, when there is a reference to the sequence per se the suffix is omitted, but when there is a reference to individual elements within the sequence the suffix is included.

Detailed Description of the Invention

Figure 1 shows a radar system 1 within which embodiments of the invention operate, the radar system 1 comprising a power source 10, a controller 12, and a computer 14, the power source and computer 10, 14 being arranged to provide power to, and operational control over, the controller 12. The controller 12 comprises a microprocessor and a set of instructions (not shown) for execution thereby, effectively generating control signals that cause the RF frequency source, or signal generator 16, to output RF energy at a specified frequency F_{OUT}, and this output signal, under control of amplifiers 20, drives antenna 22. As will be described in more detail below, the RF frequency source 16 generates signals within a range of frequencies, causing the antenna 22 to transmit beams in different angular directions, thereby scanning over a region beyond the radar system 1.

The radar system 1 also includes a receiving antenna 32, which receives radiated signals reflected back from objects, and passes the received radiation through amplifier components 20' to mixer 34. The mixer 34 comprises two inputs: a first connected to the RF source 16; and a second connected to the receiving antenna 32. The output of the mixer 34 is fed to an Analogue to Digital converter ADC 36, to produce a digitised signal for input to the signal processor 38, which performs analysis of the received signal. The signal processor 38 performs a spectral analysis on the received signals, because the range between the radar system and external (reflecting) objects is contained as frequency information in the signal.

It will be appreciated from the foregoing that the antennas 22, 32 transmit and receive radiation in response to input signals of varying frequencies; accordingly the antennas 22, 32 are of the frequency scanning antenna type. In a preferred embodiment, the frequency scanning antenna is embodied as a travelling wave antenna structure comprising at least two array antennas, one such antenna array 200 being shown in Figure 2a. In one arrangement, the antenna array comprises a mesh structure 201 and a dielectric base 203 and has input means 207 for inputting energy to the mesh structure 201. The input means 207 can comprise coaxial feeds positioned orthogonal to the plane of the antenna array 200, but the skilled person will appreciate that alternative feeds could be used.

In the arrangement shown in Figure 2a, each mesh structure 201 comprises a plurality of rectangular interconnected elements 209 that are disposed on a surface of the dielectric base 203, the dielectric base 203 being supported on a ground plane. Each rectangular element 209 comprises two sides 213a, 213b and two ends 211a, 211b, the length L of the sides 213a, 213b being greater than the length S of the ends 211a, 211b. The physics underlying the operation of the travelling wave antenna are well known, having first been investigated by John Kraus and described in US patent US 3,290,688. Suffice to say that the length L of the sides 213 is of the order of one wavelength of the mean carrier frequencies, and the length S of the ends 211 is of the order one half of the wavelength of the mean carrier frequencies. It will be appreciated from the teaching in US patent US 3,290,688 that mesh configurations other than rectangular and planar can be used.

In relation to the particular configuration adopted for embodiments of the invention, when current is fed through the mesh structure 201 via feed 207, currents passing through the ends 211a, 211b are in phase with one another. The current flowing through a respective side 213a of a given element 209 is received from an end 211a of an adjacent element (shown as input 217) and splits into two current flows, each flowing in a different direction and being out of phase with one another. As is also shown in Figure 2a, the width of the mesh making up sides 213a, 213b is progressively decreased from the centre of the mesh to each respective end thereof, thereby effectively increasing the length of the sides 213a, 213b from the centre of the array towards its ends. In a preferred arrangement the antenna can be embodied as a micro circuit strip.

The configuration of the antenna structure 301 according to an embodiment of the invention will now be described with reference to Figures 3 and 4. Figure 3 shows a development of the radar system 1 shown in Figure 1, including two antennas each embodied in the form of antenna array 200a, 200b shown in Figures 2a and 2b, and the antenna structure 301 is responsive to input from the controller 12 for controlling input of energy to respective feeds I_1, I_2 of the antenna arrays 200a, 200b. Referring also to Figure 4a, the two planar array antennas 200a, 200b are disposed within the structure 301 such that, for any given radio frequency, the antenna structure 301 is capable of transmitting the radio frequency energy within different angular regions 401a, 401b.

Referring back to Figure 3, the antenna structure 301 can be characterised by a longitudinal axis A1 and a transverse axis A2, which provides a convenient frame of reference for describing the arrangement of the planar antenna arrays 200a, 200b. As can be seen from Figure 3, the first array antenna 200a is inclined at an angle α relative to said transverse axis A2 and the second planar array antenna 200b is inclined at angle β relative to the transverse axis A2. As can also be seen from the Figure, a side portion of said second array antenna 200b abuts a side portion of said first array antenna 200a (in the Figure the side portions are located on the dot indicating axis A1) such that when viewed face on, the antenna arrays 200b are located in adjacent longitudinal planes.

It will be appreciated from the schematic shown in Figure 4a that the orientation of the respective antenna arrays 200a, 200b – that is to say angles α and β – determine the direction in which radiation is emitted from the antenna structure 301. Thus, by varying the relative positions of the respective antenna arrays 200a, 200b, different portions of an angular region can be scanned for a given output frequency, $f_{OUT,1}$.

Figure 4b shows radiation emitted 401a – 401d from the antenna arrays for two different output frequencies $f_{OUT,1}$ and $f_{OUT,2}$, and it can be seen that appropriate selection of the values of $f_{OUT,1}$ and $f_{OUT,2}$, results in the antenna structure 301 outputting radiation so as to cover a substantially contiguous region, thereby scanning over a greater angular region than is possible with a single antenna array, or even two arrays that are positioned in the same plane, such as that described in US patent US 4,376,938.

The arrangements shown in Figures 2a, 3, 4a and 4b relate to an arrangement in which the antenna arrays 200a, 200b comprise a single feed I_1, I_2 at one end of respective antenna arrays. However, and referring to Figures 2b and 5, each antenna array could comprise an additional feed at its other end ($I_{1,2}$, $I_{2,2}$). Each antenna 22a, 22b can then be considered to be capable of emitting radiation in two directions for a given frequency f_{OUT}, since the transceive-behaviour of the antenna array 200a is dependent on the direction from which energy is fed into the antenna. Turning to Figure 6, it can be seen that by feeding energy to two input feed points for each antenna array, the region R within which radiation can be transceived is effectively doubled.

In the above passages the radar system 1 is assumed to comprise a separate transmit and receive antenna structure 301, 303. However, and turning to Figure 7, the radar system 1 could alternatively comprise a single antenna structure 301 and a circulator 40, which, as is known in the art effectively combines signals that are transmitted and received from the antenna structure 301.

Figure 8 shows an alternative configuration of the antenna arrays 200a, 200b within an antenna structure 301, in which each the antenna array 200a, 200b is located on a respective support structure, an outer edge 231a of one support structure abutting a corresponding outer edge 231b of another support structure so as to form an antenna structure having a generally isosceles shape; since the supports of respective antenna arrays abut one another the radar system can be fabricated such that receiving antenna structure 301 abuts transmitting antenna structure 303, thereby generating a physically smaller radar system, in terms of depth occupied by the antenna structure, compared to that shown in

Figure 3. It will be appreciated that other configurations are possible, involving two, three or several such antenna arrays mounted on suitable support structures.

The above embodiments are to be understood as illustrative examples of the invention. Further embodiments of the invention are envisaged. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

Claims

1. A frequency scanning antenna structure for transceiving radio frequency energy and being capable of steering a radio frequency beam to a plurality of different angles about the antenna structure, the antenna structure comprising at least two array antennas and a controller for controlling input of energy to the two array antennas, wherein the array antennas are disposed within the antenna structure such that the antenna structure is capable of steering a beam to a first angle using one of said two array antennas and of steering a beam to a second angle, different to said first angle, using the other of said two array antennas.

2. A frequency scanning antenna according to claim 1, wherein the antenna structure is capable of steering a beam across a plurality of non-contiguous angular regions.

3. A frequency scanning antenna according to claim 1 or claim 2, wherein the antenna structure is capable of steering a beam across a substantially contiguous angular region.

4. A frequency scanning antenna according to any one of the preceding claims, wherein the antenna structure is capable of steering a beam across a first range of angles using one of said two array antennas and of steering a beam across a second range of angles using the other of said two array antennas.

5. A frequency scanning antenna according to claim 4, wherein a first angular region is defined by said first range of angles.

6. A frequency scanning antenna according to claim 4 or claim 5, wherein a second angular region is defined by said second range of angles.

7. A frequency scanning antenna according to any one of claim 4 to claim 6, wherein said first range of angles is different to said second range of angles.

8. A frequency scanning antenna according to any one of claim 2 to claim 7, wherein the angular region is substantially 80 degrees.

9. A frequency scanning antenna according to any one of the preceding claims, wherein each said array antenna comprises input means for inputting said energy thereto.

10. A frequency scanning antenna according to any one of the preceding claims, wherein the controller is arranged to input energy to respective array antennas so as to steer the beam to said first and second angles.

11. A frequency scanning antenna according to claim 9 or claim 10 when dependent on claim 3, wherein each input means is arranged to input energy to respective array antennas so as to steer the beam across said substantially contiguous angular region.

12. A frequency scanning antenna according to claim 9 or claim 10 when dependent on claim 2, wherein, for a given array antenna, the input means is arranged to input energy to the array antenna at two locations so as to steer the beam across said non-contiguous angular region.

13. A frequency scanning antenna according to any one of claim 9 to claim 12, wherein the input means is connectable to ends of the antenna array.

14. A frequency scanning antenna according to any one of claim 9 to claim 13, wherein the input means is arranged in operative association with a

signal generator so as to receive signals comprising radio frequency energy at a plurality of different frequencies so as to steer the beam.

15. A frequency scanning antenna according to any one of claim 9 to claim 14, wherein the controller is arranged to input energy in accordance with a predetermined sequence so as to steer the beam across said first and second angles.

16. A frequency scanning antenna according to claim 15, wherein the predetermined sequence includes a inputting energy to a first end of the first antenna array, inputting energy to a first end of the second antenna array, inputting energy to a second end of the second antenna array, and inputting energy to a second end of the second antenna array.

17. A frequency scanning antenna according to any one of the preceding claims, said antenna structure having a longitudinal axis and a transverse axis perpendicular to said longitudinal axis, wherein a first of said array antennas is inclined at said first angle relative to said transverse axis and a second of said array antennas is inclined at said second angle relative to said transverse axis.

18. A frequency scanning antenna according to claim 17, wherein each of said array antennas comprises two ends and two side portions, a side portion of said second array antenna substantially abutting a side portion of said first array antenna.

19. A frequency scanning antenna according to claim 17 or claim 18, wherein the first and second array antennas are symmetrically disposed about the longitudinal axis.

20. A frequency scanning antenna according to any one of the preceding claims, each said array antenna comprising a mesh structure and a dielectric base.

21. A frequency scanning antenna according to claim 20, each mesh structure comprising a plurality of interconnected elements and being disposed on a surface of a corresponding said dielectric base.

22. A frequency scanning antenna according to claim 21, wherein each of said elements comprises two sides and two ends of respective lengths, the length of said sides being greater than the length of said ends, wherein the length of the sides is of the order of one wavelength at a mid-point between said first frequency and said second frequency and the length of the ends is of the order one-half of one wavelength at said mid-point frequency.

23. A scanning radar system according to claim 21 or claim 22, the sides of each element having a width, wherein the width of the sides is progressively decreased from the centre of the mesh to each respective end thereof, so as to control the impedance of the array antenna.

24. A frequency scanning antenna according to claim 21 to claim 23, wherein each said element in the mesh structure comprises a rectangular element.

25. A frequency scanning antenna according to any one of the preceding claims, wherein each said array antenna comprises a planar array antenna.

26. A frequency scanning antenna according to any one of the preceding claims, wherein each said array antenna comprises a micro circuit strip.

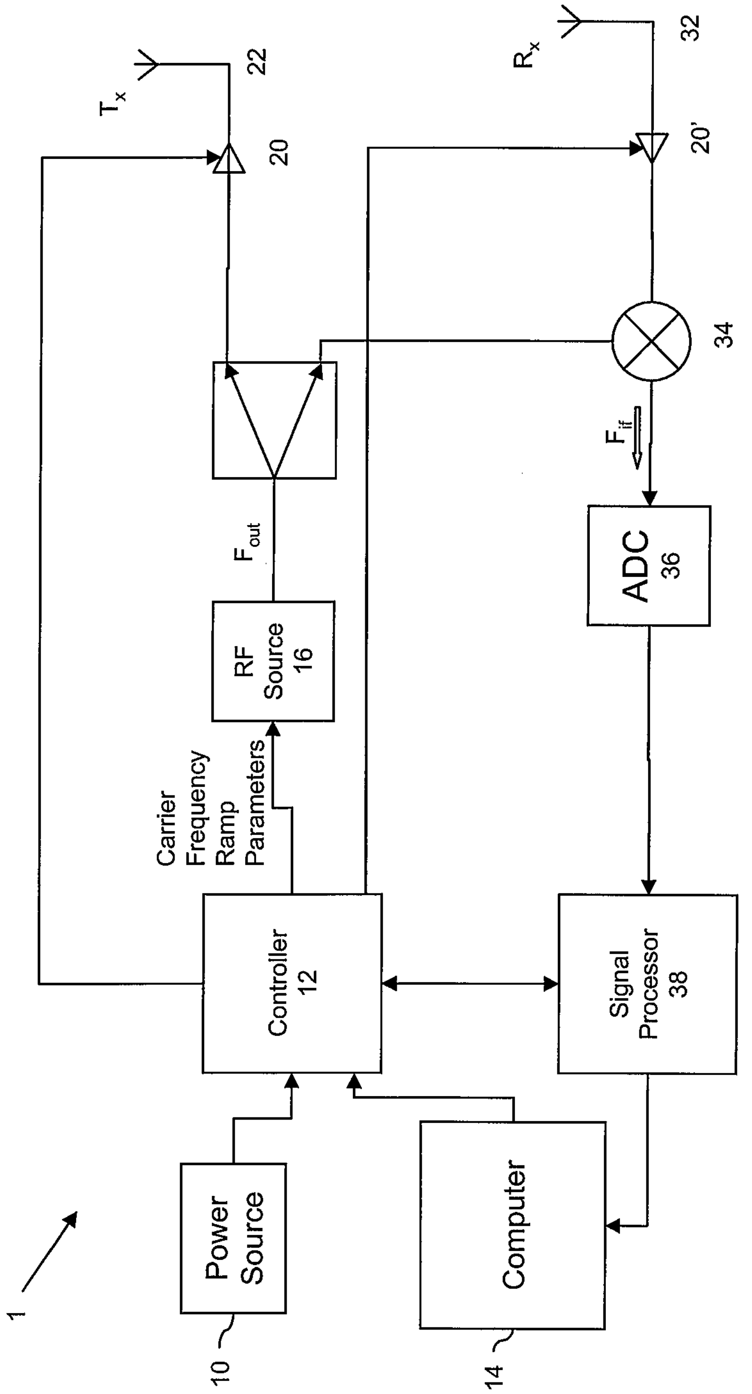

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FIG. 1

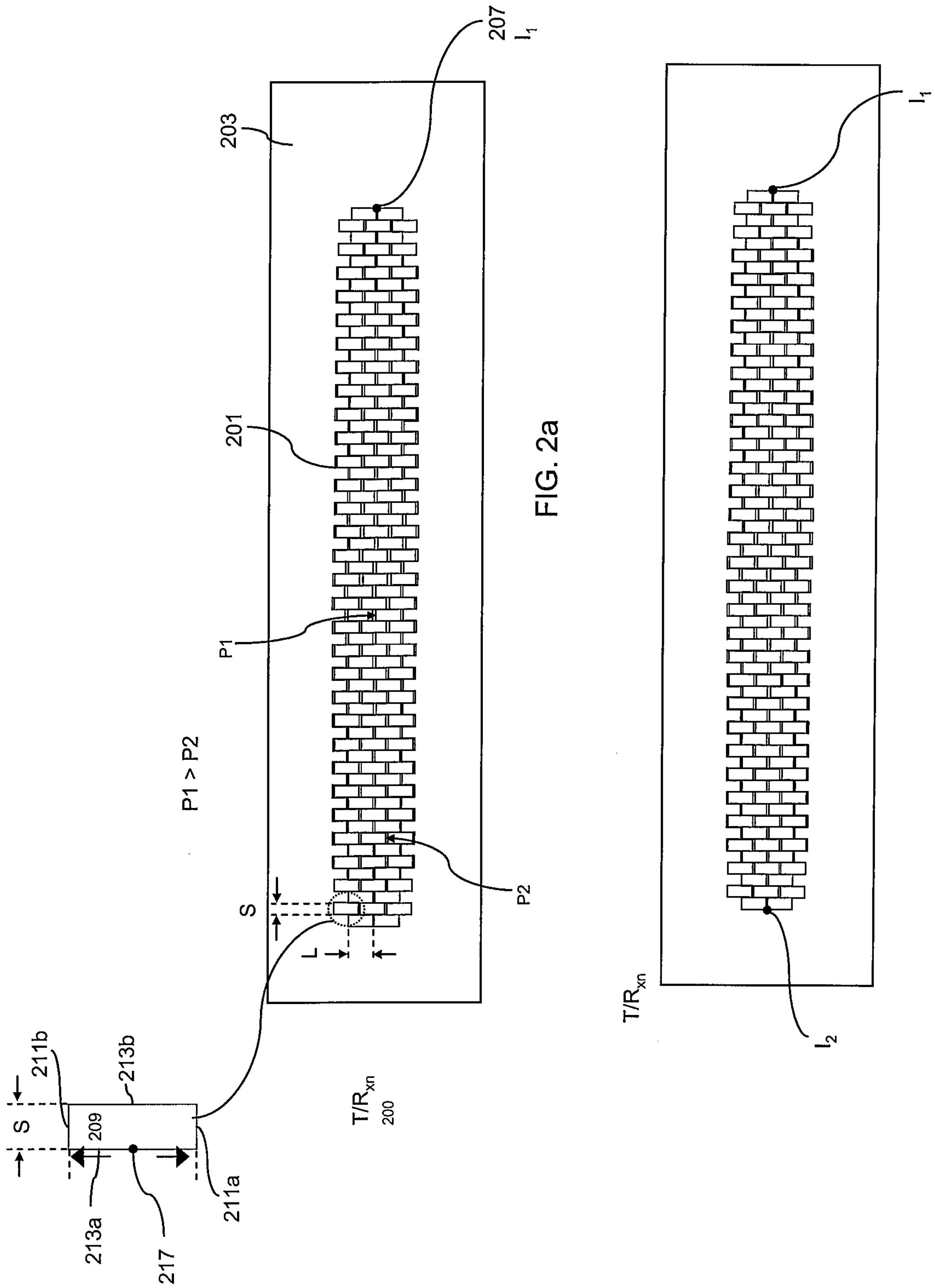
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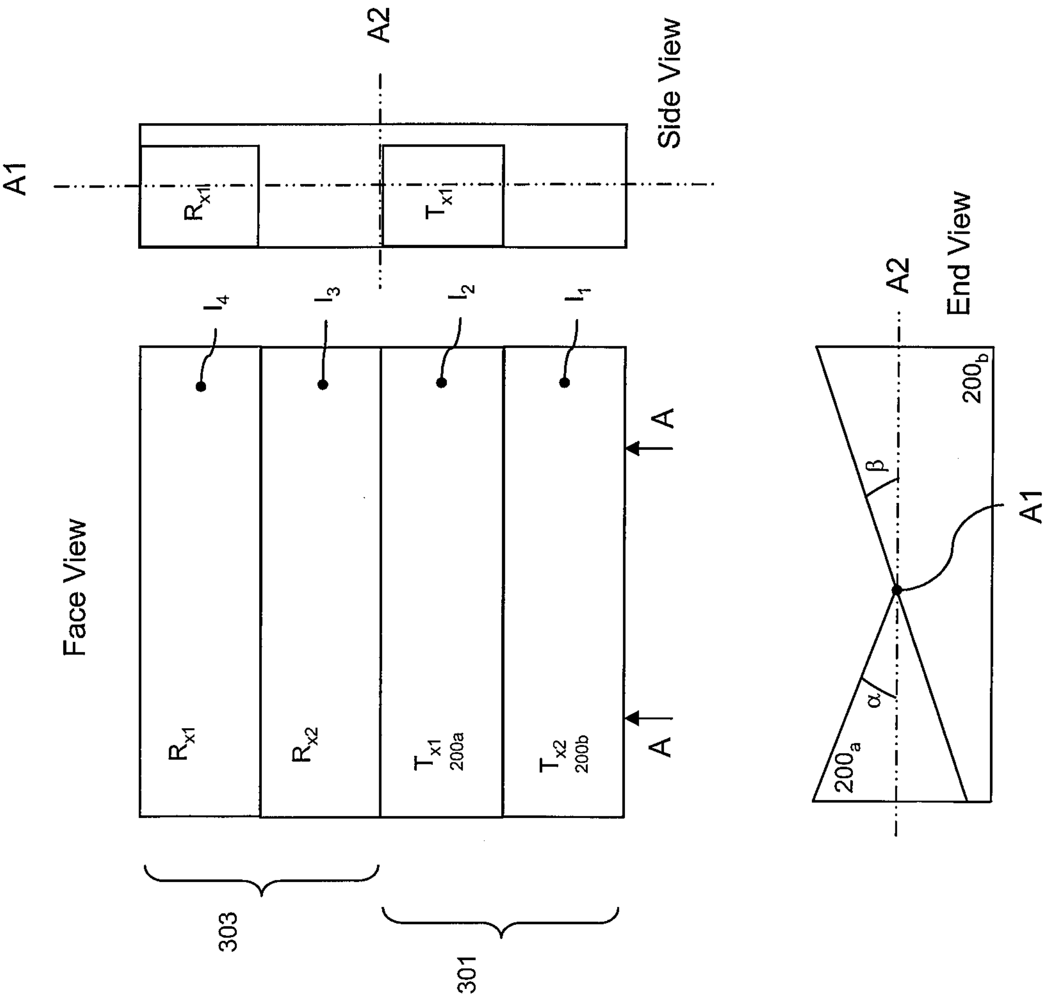
FIG. 2a

FIG. 2b

FIG. 3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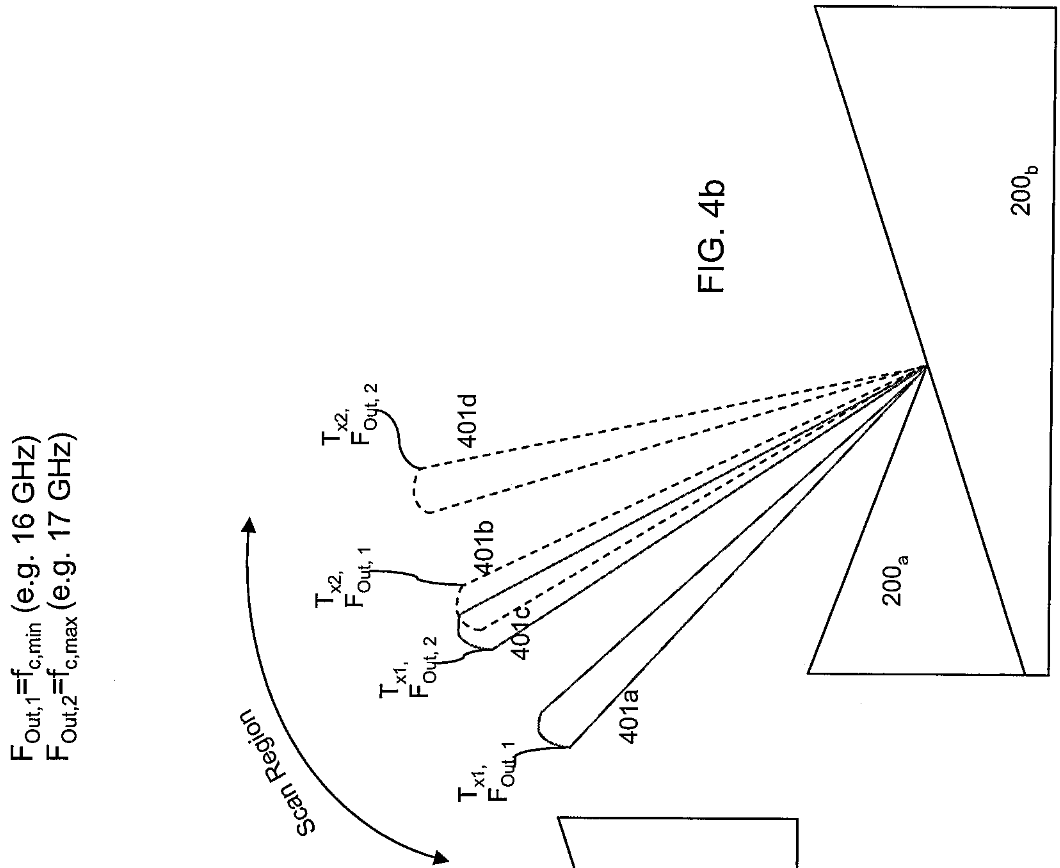

FIG. 4b

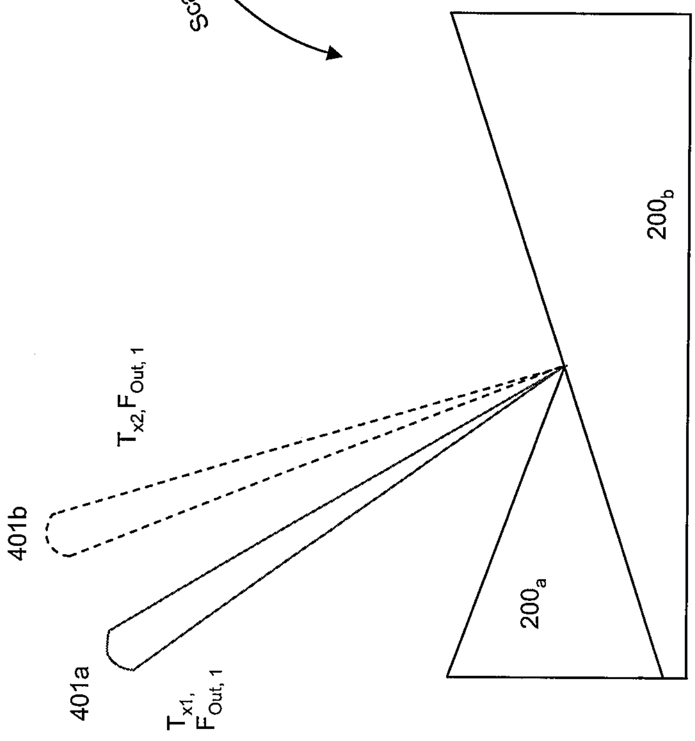

FIG. 4a

Views on end A-A

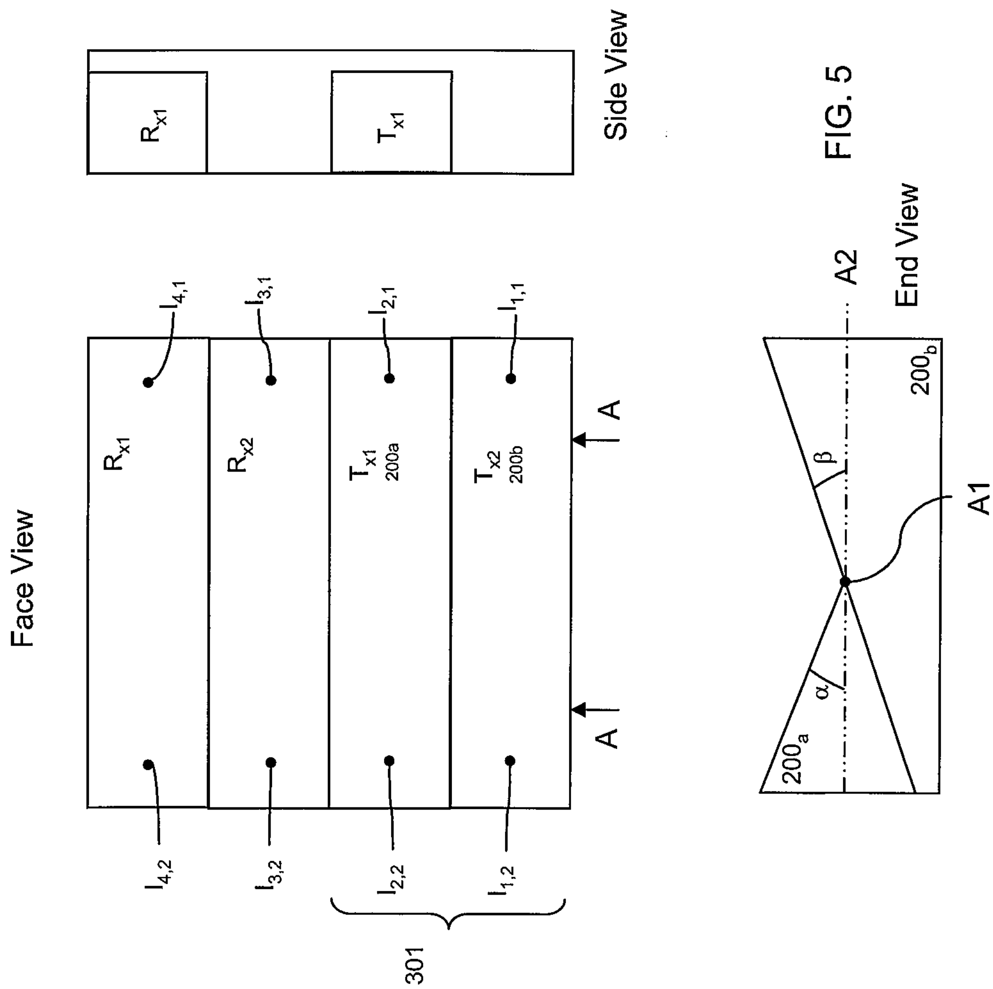
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FIG. 5

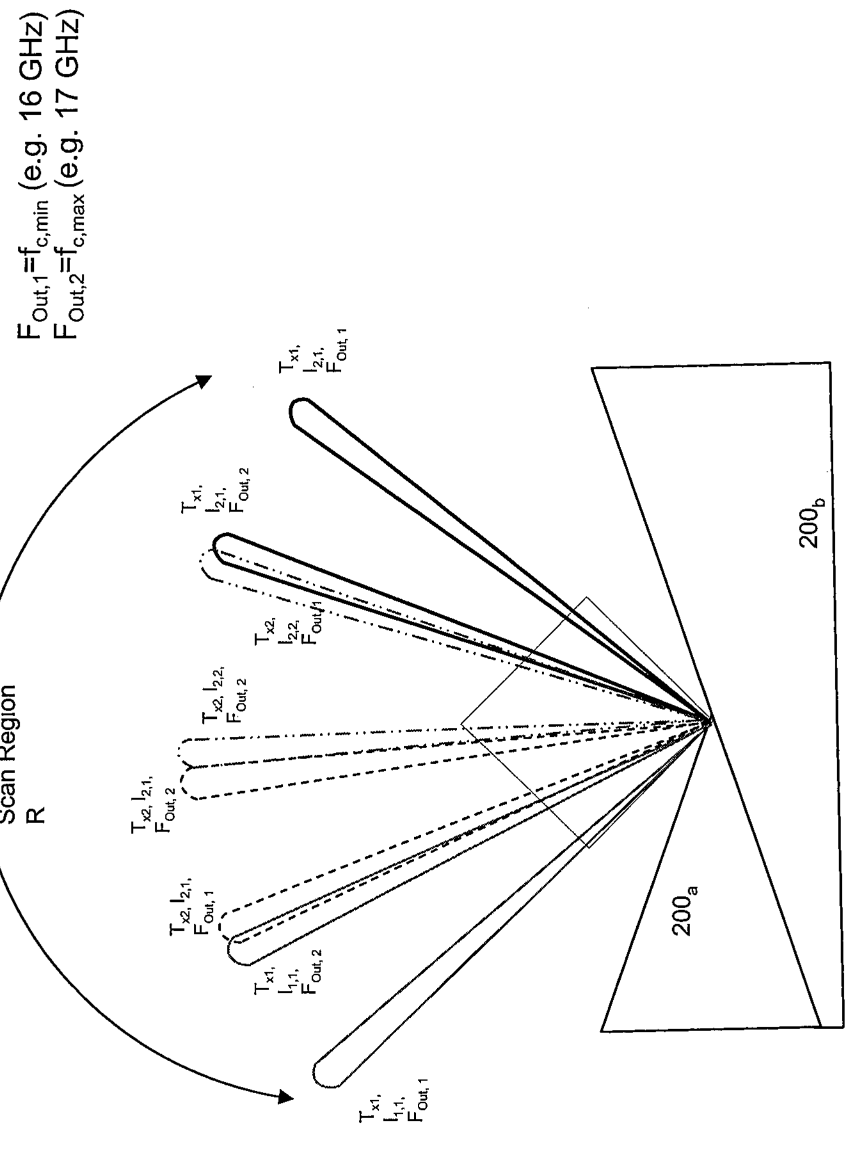
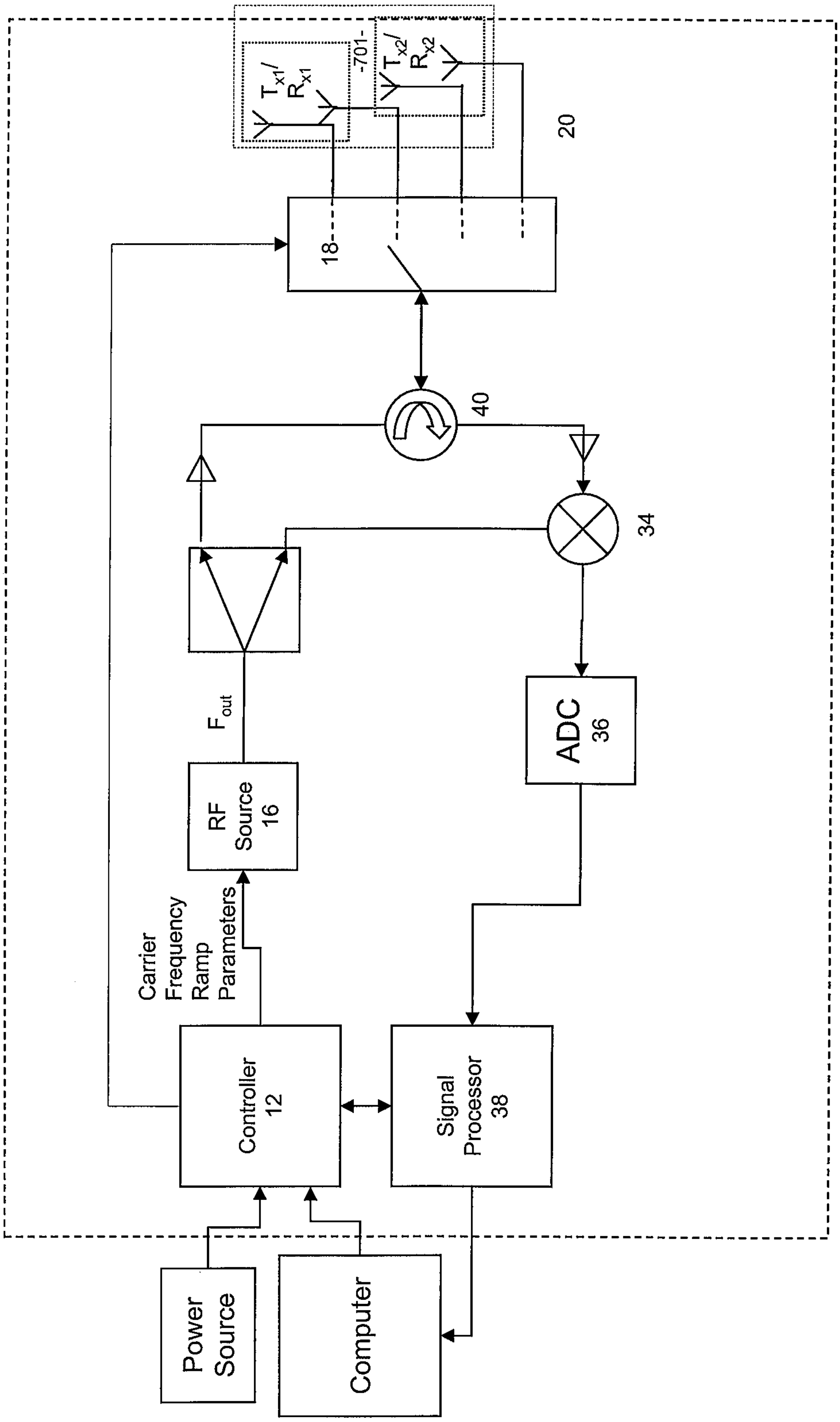


FIG. 6

View on end A-A

MSOffice2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Signal Processor 38
Power Source
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FIG. 7

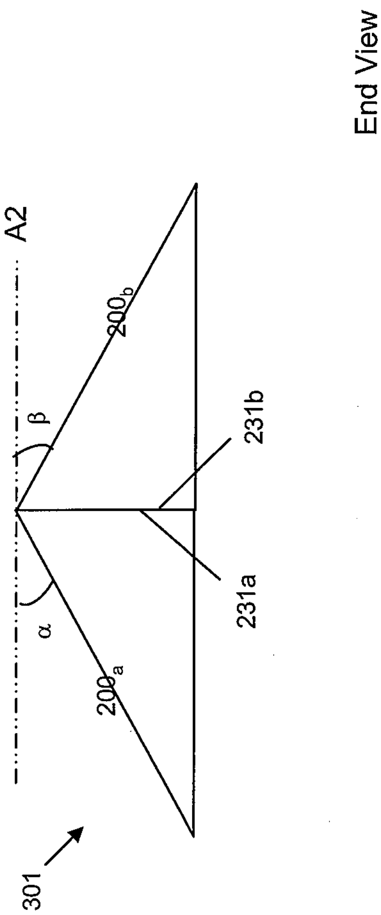

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/068732

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q3/22 G01S13/42

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)
G01S 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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2004/046752 A (DAIMLER CHRYSLER AG [DE]; MAYER WINFRIED [DE]; SCHNEIDER ROBERT [DE]) 3 June 2004 (2004-06-03) pages 6-13; figures 1-4	1-15, 17-19
Y	US 5 969 689 A (MARTEK GARY ALLEN [US] ET AL) 19 October 1999 (1999-10-19) the whole document	1-26
Y	US 3 290 688 A (KRAUS JOHN D) 6 December 1966 (1966-12-06) cited in the application the whole document	1-26

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

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 April 2007	02/05/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	FANJUL CAUDEVILLA, J

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	IBRAHIM TEKIN ET AL: "SIMULTANEOUS FREQUENCY AND DIRECTION FINDING TECHNIQUE USING FREQUENCY SCANNING ANTENNA" PROCEEDINGS OF THE EUROPEAN MICROWAVE CONFERENCE. ESPOO, FINLAND, AUG. 24 - 27, 1992, TUNBRIDGE WELLS, MEP, GB, vol. VOL. 1 CONF. 22, 24 August 1992 (1992-08-24), pages 654-658, XP000337824 abstract; figure 1	1-15
A	US 4 376 938 A (TOTH JOHN F ET AL) 15 March 1983 (1983-03-15) column 2, lines 29-65; figures 1,2A,2B	20-26
A	US 4 868 574 A (RAAB ANTHONY R [CA]) 19 September 1989 (1989-09-19) column 4, paragraph 44-53; figure 4	16
A	US 5 459 474 A (MATTIOLI JOSEPH A [US] ET AL) 17 October 1995 (1995-10-17) abstract; figures 1,2	17-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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