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(54) SLOT ANTENNA AND METHOD FOR OPERATING THE SAME

SCHLITZANTENNE UND VERFAHREN ZU IHREM BETRIEB

ANTENNE À FENTES ET SON PROCÉDÉ D'UTILISATION

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of planar antennas. More particularly, this invention relates to the field of planar array antennas. Further in more detail, the present invention relates to the field of slot waveguide array antennas suited to transmit and receive a circularly polarized electromagnetic wave.

BACKGROUND OF THE INVENTION

[0002] Slot waveguide antennas are widely used in many applications and connection links. In particular, waveguide-fed planar slot antennas have been used in a number of ground- and space-based radar and communications systems, because of their favorable features such as small volume and weight, and ease of deployment, opposite to traditional parabolic antennas, characterised by high volume and encumbrance. This latter kind of antennas is not suited to particular applications such as communications on the move, a sector whose interest has been steadily increasing because of the market demand.

[0003] In highly demanding applications, the design and the analysis of planar slot antennas, comprising one or more slots on a broadwall for coupling and emitting/receiving the radiation, have reached a mature state, providing industries and users with low volume and easy-to-use antennas, capable of combining the emitting and the feeding elements in a space-efficient unit.

[0004] As an example, US6657599 discloses a slot antenna having a feeding waveguide extending in a longitudinal direction for guiding electromagnetic waves, with at least one slot constructed in a broadwall of the waveguide for emitting an electromagnetic wave. According to US6657599, the slot is surrounded on the exterior side of the waveguide by an arrangement for rotating the polarization direction of the electromagnetic wave emitted by the slot itself.

[0005] Furthermore, recently new planar slot antennas have been investigated, leading to more efficient solutions, teaching the use of waveguide-fed planar slot antennas in planar arrays.

[0006] Planar arrays have been well-known and used in many applications. Planar arrays are based on the principle of achieving a target emitted field distribution by employing an array of radiant elements fed with proper amplitude and phase signals.

[0007] Besides the encumbrance reduction, planar arrays allow the user to modify the radiated beam pointing by varying the characteristics (amplitude and phase) of the signal fed to each radiating element. This technique is known as Beam Steering and requires a radiant element supply network which is complex and expensive, especially when highly demanding radio-electric performances are required, e.g. in a satellite link.

[0008] In these circumstances, a goal is to simplify as much as possible the supply of the Beam Steering Network, so as to meet budget constraints. Waveguide-fed planar slot arrays represent a possible solution to the problem, as is pointed out by WO9733342, which discloses a waveguide-fed slot array antenna comprising a plurality of slots for transmitting or receiving circularly polarized electromagnetic waves.

[0009] Besides these known solutions, further investigations have been directed towards the control of the polarization of the electromagnetic wave emitted by slot-ted waveguides, in particular by properly designing the slot shape, as well as their position along the waveguide.

[0010] As an example, US2001/0028329 discloses an antenna comprising slots arranged pairwise, preferably at 90 degrees to one another and at ± 45 degrees with respect to the longitudinal direction of the waveguide, and a transceiver adapted for controlling the polarization modes.

[0011] As a further example, document JP2002185237 discloses a system of varying polarized waves, which comprises a slot array antenna formed by a symmetrical structure in which a plurality of truncated-chevron-shaped paired slots are provided in a waveguide path. Document JP54096389 discloses a circularly polarized wave slot antenna wherein a strip-line conductor is enclosed in a guiding structure, which comprises a plurality of slot pairs. Document WO99/07033 discloses an antenna formed by parallel waveguides of rectangular or ridged cross section, the broadwall of each parallel waveguide containing an array of input slots for receiving a signal and for transmitting this signal to an array of cavity sections, which feed output slots, which are rotated relative to the input slots. Furthermore, Mazzarella G. et al., "Waveguide slot antennas for circularly polarized radiated field", IEEE Transactions on Antennas and Propagation, IEEE Service Center, Piscataway, NJ, US, vol. 52, no. 2, 01.02.2004, pages 619-623 discloses a waveguide slot configuration to radiate a circular polarization, which consists of two closely spaced radiating slots.

[0012] Making reference to the cited prior art, the Applicant noted that, despite the noticeable amount of documents relating to slot waveguide antennas in general and, to a lesser extent, slot waveguide array antennas, there is the need for a new antenna, capable of overcoming at least in part the drawbacks of the prior art.

[0013] In particular, US2001/0028329 mainly addresses the problem of the polarization control of the radiation emitted by a slot waveguide. Arbitrary polarization modes can be achieved by means of a complex structure, including circulators, filters and/or a control unit made up of diodes. Furthermore, US2001/0028329 does not provide the reader with any suggestion about how to obtain a good working bandwidth.

[0014] WO9733342 discloses a double polarization slot waveguide antennas which is used only as receiving antenna, working at a single, nominal frequency.

OBJECT AND SUMMARY OF THE INVENTION

[0015] Therefore, the aim of the invention is to devise a dual polarization circular antenna solving the problems encountered by the prior art. According to the invention, there are provided a slot antenna and a method for operating an antenna, according to claim 1 and, respectively, claim 15.

GRIEF DESCRIPTION OF THE DRAWINGS

[0016] For the understanding of the present invention, a preferred embodiment is now described, purely as a non-limitative example, with reference to the enclosed drawings, wherein:

- Figure 1 is a perspective view of an electro-mechanical Beam Steering system;
- Figure 2 is a perspective view of the arrangement of radiant elements in a row-wise array planar antenna;
- Figure 3 is a perspective simplified view of a single-ridge slot waveguide antenna;
- Figure 3a shows the single-ridge waveguide connected to a switch;
- Figure 4 is a detailed, top view of the single-ridge slot waveguide of figure 3;
- Figures 5a and 5b shows the depointing effect within two bands for the single-ridge slot waveguide antenna of Figure 3; and
- Figures 6, 7a and 7b show block diagrams of an antenna system incorporating the waveguide antenna of Figure 3.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0017] Figure 1 shows an electro-mechanical Beam Steering system 1 using a double electro-mechanical scansion technique, characterized by a simple control of the radiation pattern. The system 1 comprises a base 2; a support 3, rotatably carried by the base 2; and an antenna 4, fixed to the support 3. In a per se known manner, the antenna 4 comprises one or more radiant elements, only one whereof (indicated in figure 1 by 5) is visible in figure 1.

[0018] In the system 1, according to the double electro-mechanical scansion technique, the elevation is electronically controlled by supplying electromagnetic signals, as known to the person skilled in the art, whereas the azimuth is varied by using mechanical means, not shown. Such a technique provides a simple scan solution, wherein the electronic scansion involves just one axis, allowing the use of a planar, compact structure.

[0019] Usually, the steering of the beam irradiated by planar array antennas is achieved by varying the amplitude and/or the phase of the signal supplied to each radiant element 5, but the electronic scansion may be performed by rows, as shown in figure 2, relating to a row-

wise managed array antenna, wherein the radiant elements 5 are arranged along a plurality of parallel rows 6. In the considered application field, the radiant elements 5 are made up of slots located on a waveguide, as discussed in more detail with reference to Figure 3.

[0020] The signals supplied to the rows 6 may be phase shifted to one another, as represented in figure 2 by phase shifters 7.

[0021] In the antenna 4 of Figure 2, all the radiant elements 5 belonging to the same row 6 irradiate with a fixed phase, whereas the phase variation introduced between the rows 6 induces a change of the radiation pattern in planes orthogonal to the rows 6.

[0022] From a practical point of view, each array row 6 acts as a subarray with fixed broadside pointing and can be supplied by a single port 10, to which the phase-shifters 7 are connected.

[0023] To overcome the problem of high insertion losses affecting this kind of Beam Steering networks, the present solution adopts a waveguide feeding mechanism. In fact, insertion losses are detrimental to the overall performances of the system comprising the antenna, whichever its application is, since they badly affect the antenna noise temperature and, consequently, the reception capabilities of the antenna.

[0024] Unfortunately, rectangular waveguides are characterised by high encumbrance and dimensions. Therefore, they are not compatible with the row spacing required in some applications. In fact, the possibility of scanning the lobe on planes orthogonal to the rows 6 requires that the spacing between two adjacent rows 6 be small enough to avoid grating lobes within the scanning angle.

[0025] In order to overcome this problem, the present antenna 4 adopts a single-ridge waveguide feeding system, as shown in figure 3. In fact, this kind of waveguide allows to obtain low cutoff frequencies, low encumbrances, low insertion losses, as well as a good resilience to dispersion, thus allowing for large overall working bandwidths.

[0026] In detail, Figure 3 shows a single-ridge waveguide 13 formed by a tubular encasing 14a, e.g. of metal material, surrounding a cavity 14b. The cavity 14b may be filled by a suitable material, e.g. by dielectric material, as known to the person skilled in the art. The single-ridge waveguide 13 has a generally parallelepipedal shape with a top face, hereinafter indicated as waveguide broadwall 12, and a lower face 15. Slots 11 are formed in the waveguide broadwall 12, while a longitudinal groove 19 extends along the single-ridge waveguide 13, open toward the lower face 15. The waveguide broadwall 12 further has a longitudinal axis A (hereinafter indicated as a broadwall axis A); the single-ridge waveguide 13 has a first input/output port 10a and a second input/output port 10b.

[0027] According to Figure 3, each radiant element 5 is made up of a couple of slots 11 having the shape discussed below in detail, so as to achieve a circular polar-

ization for the emitted and received electromagnetic field.

[0028] In slot waveguide antennas the phase delay between two different slots 11 or two different radiant elements 5 is ruled by the phase of the signal propagating within the single-ridge waveguide 13, and such a phase delay may be regulated simply by choosing the distance between the two slots 11 or the two radiant elements 5 along the broadwall axis A. In turn, the phase of the signal propagating within the single-ridge waveguide 13 is determined by the wavelength of the guided radiation, so that it is strictly connected to the single-ridge waveguide 13 geometry.

[0029] In the present case, the arrangement of the radiant elements 5 is such as to create a radiant subarray, whose radiant elements 5 are fed in series and with a "travelling wave supply". In particular, this "travelling wave supply" is achieved by using a matched waveguide, fed e.g. at the first input/output port 10a; a travelling wave propagates within said single-ridge waveguide 13 from the first input/output port 10a up to the second input/output port 10b, and feeds the radiant elements 5.

[0030] In detail, as shown in Figure 4, the slots 11 on the top broadwall 12 are equally shaped and the two non-overlapping slots 11a and 11b forming a radiant element 5 are arranged on opposite sides with respect to the broadwall axis A. The slots 11a and 11b are preferably elongated and extend from the longitudinal edges of the broadwall 12 towards the broadwall axis A, so that their longitudinal axes 23 form, with the broadwall axis A, angles equal to ± 45 degrees. In practice, the longitudinal axes 23 of the slots 11 of a single radiant element 5 form a 90 degree angle with each other. Moreover, as shown in Figure 4, the slots 11 are tapered towards the broadwall axis A to form tips 24. Furthermore, for a given guide wavelength λ_g , the longitudinal distance $d1$ between two slots 11 belonging to a same radiant element 5 is equal to a quarter of the guide wavelength, wherein in the present context the longitudinal distance $d1$ indicates the distance between the barycenters of the geometrical figures formed by the two slots 11 in the direction of the broadwall axis A. From a practical point of view, two slots 11 belonging to a same radiant element 5 are mutual mirror images with respect to the broadwall axis A, shifted along the same broadwall axis A by the distance $d1$.

[0031] The radiant elements 5 are grouped in radiant element groups comprising two adjacent radiant elements 5a and 5b, the radiant element groups being equal to each other, equally oriented with respect to the broadwall axis A, and longitudinally spaced from the adjacent element groups by multiples of the guide wavelength λ_g . More in detail, being 11a and 11b, respectively, the first and the second slots forming a first radiant element 5a of a radiant element group, and 11c and 11d, respectively, the first and the second slots of a second radiant element 5b of the same radiant element group, the group geometry is the following (please refer again to Figure 4): the slots 11a and 11c lie along opposite, parallel directions on opposite sides of the broadwall axis A; the

slots 11b and 11d lie along opposite, parallel directions on opposite sides of the broadwall axis A, and extend orthogonally to the slots 11a and 11c. In other words, the first and second radiant elements 5a and 5b are arranged specularly with respect to an axis perpendicular to the broadwall axis A.

[0032] In addition, the distance $d2$ between the barycenters of the geometrical figures formed by the two slots 11a and 11c in the direction of the broadwall axis A is equal to half a guide wavelength $\lambda_g/2$; analogously, the distance between the barycenters of the geometrical figures formed by the two slots 11b and 11d in the direction of the broadwall axis A is equal to half a guide wavelength $\lambda_g/2$, so that the radiant elements 5a and 5b are longitudinally spaced by half a guide wavelength $\lambda_g/2$. In the present illustrative example the slot tips 24 are aligned on the broadwall axis A.

[0033] In the above description, λ_g is the guide wavelength at the nominal working frequency (central frequency).

[0034] The described arrangement allows the obtaining of a compact single-ridge waveguide 13. In principle, with radiant elements 5 equal and equally oriented along the broadwall axis A, in order to have the radiant elements 5 emitting in phase, it is sufficient to space them along the broadwall axis A at distances $d3$ multiple of the guide wavelength λ_g . In the embodiment of Figures 3 and 4, where the radiant elements 5 are made up of two slots 11 not overlapping nor lying on the same side of the broadwall axis A, in order to have a phase matching condition among parallel slots 11 within the same radiant element group, it is sufficient to longitudinally space these parallel slots 11 along the broadwall axis A by $\lambda_g/2$. In fact, the remaining 180 degrees required to achieve the phase matching condition are given by the fact that the parallel slots, e.g. 11a and 11c, within the same radiant element group are arranged on opposite broadwall sides with respect to the broadwall axis A. In addition, the phase matching condition among different radiant element groups is achieved by arranging them along the broadwall axis A at distances $d3$ multiple of one guide wavelength λ_g . The radiant elements 5a and 5b so arranged provide the same polarized field, when fed from the propagating wave within the single ridge guide. Furthermore the average distance between the radiant elements is so reduced, avoiding the grating lobe effect.

[0035] The above indicated distances and geometrical arrangements may slightly vary in practical implementation, due to effects of coupling between the slots 11 and effects of variation of the guide wavelength λ_g due to perturbations in wave propagation within the waveguide caused by the slots themselves. For example, distances and geometrical arrangements may vary of about 20% of their nominal value.

[0036] The present geometry guarantees several functional and geometrical advantages with respect to known slot waveguide antennas, as discussed hereinbelow in comparison to known waveguide slot antennas.

[0037] In known waveguide antennas, when the frequency varies, a beam tilting occurs, because the ratio between the radiant element distance and the guided wave wavelength changes, resulting in a phase mismatch between the radiant elements and causing a variation of the radiation pattern.

[0038] Furthermore, usual "travelling wave" structures, employing radiant elements consisting of a single slot, show a low efficiency in the broadside direction. From a qualitative point of view, this effect may be understood figuring out such an antenna working in reception, with a plane wave coming across the antenna, with a wave front lying in the array plane. When this situation occurs, all the radiant elements are interested by the same field, so they are excited in phase, preventing a travelling wave from travelling towards one of the two waveguide ends, that is towards one of the waveguide input/output ports. In practice this effect provides a mismatching at the port of the waveguide, at the frequency of broadside pointing. If the wave front is not orthogonal to the broadside direction, a phase difference between the slots arises, exciting a travelling wave towards one of the two waveguide input/output ports.

[0039] The solution of the above problem, as well the emission of circular polarized radiation, are obtained by using the described geometry.

[0040] In particular, when the radiant elements 5 are excited by a wave travelling within the underlying single-ridge waveguide 13, they emit a circularly polarised radiation, because each slot 11 transmits a linearly polarized wave and the two radiations emitted by the two slots, e.g. 11a and 11b, making up each radiant element 5 are orthogonal and phase delayed of 90 degrees.

[0041] Furthermore, the emission efficiency is good also in the broadside direction, indicated by B in figure 5a. In fact, thanks to the 90 degree phase difference occurring between the two slots, e.g. 11a, 11b (please refer to Figure 4), of a radiant element 5 and to the electric field rotation of the circular polarization, the slots 11a, 11b excite a wave travelling within the waveguide towards one of the input/output ports 10a, 10b even if the incoming radiation is parallel to the broadside direction B.

[0042] By properly designing the single-ridge waveguide 13, the shape and the position of the radiant elements 5, it is possible to achieve a good polarization purity within relative bandwidths in the order of 15%.

[0043] Furthermore, since the radiant elements 5 belonging to the same radiant element group are arranged at distances $d_2 = \lambda_g/2$, the phase matching condition between radiant elements 5 is achieved in a more compact manner than in known slot waveguide antennas. Moreover, this geometry makes the present antenna 4 less prone to grating lobes.

[0044] From an operative point of view, the single-ridge waveguide 13 irradiates a right-hand circular polarized (RHCP) wave when the feeding travelling wave propagates in one direction, whereas it emits a left-hand polarized (LHCP) wave when the feeding travelling wave

propagates in the opposite direction. This is due to an inversion in the phase relationship among the slots 11.

[0045] More in detail, in each radiant element 5, a first slot 11 (e.g. slot 11a in Figure 4) which is in advance with respect to a second slot 11 (e.g. slot 11b) when the wave travels in a first direction, becomes delayed with respect to the second slot 11b when the wave travels in the opposite direction, causing an inversion of the rotation direction of the radiated electric field vector.

[0046] This mechanism allows to set up a system capable of separating a TX band from a RX band, and is particularly advantageous in applications, such as the satellite ones, in which the TX signal and the RX one have crossed circular polarizations.

[0047] The single-ridge waveguide 13 described above may be used so as to solve at least in part the depointing arising when departing from the design frequency, and to extend the antenna working range to both the RX band and the TX band.

[0048] The previously described technical features will be made clear by the following example, wherein the single-ridge waveguide 13 works as an antenna in the satellite X band, with RX band equal to 7, 25-7, 75 GHz and TX band equal to 7,9-8,4 GHz, and the TX and the RX bands use opposite circular polarizations, e.g. LHCP for the RX band and RHCP for the TX band. As already explained, the single-ridge waveguide 13 naturally acts so as to separate the TX and RX circularly polarized signals: the TX signal may be inputted to one port (e.g., input/output port 10b in Figure 5b), the RX signal may be outputted to the other port (e.g., input/output port 10a in figure 5b). Owing to the capability of the described antenna to work also in broadside, it is possible to define the distance between the radiant elements 5 so as to achieve a broadside pointing at a central frequency to the RX and TX bands, in the considered example, equal to 7,825 GHz. In such a way, the beam tilting within each band lays on a same side with respect to the broadside direction, thus reducing to one half the overall depointing. For example, if the single-ridge waveguide antenna 13 is fed on the first input/output port 10a (Figure 5a) with a signal in the RX band, the corresponding emitted radiation beam is tilted (for example) on the left side with respect to the broadside direction B (towards negative angles), because the distance between the radiant elements 5 is shorter than the guide wavelength λ_g in the RX band (frequency lower than the central one). On the contrary, if the same first input/output port 10a is fed with a signal in the TX band, neglecting for a moment the polarization, which does not affect the present argumentation, the beam tilting is on the right side with respect to the broadside direction B (towards positive angles), since the distance between the radiant elements 5 is longer than the guided wavelength in the TX band. In the case shown in Figure 5b, wherein the signal in the TX band is fed on the second input/output port 10b, the corresponding beam is tilted on the left side with respect to the broadside direction B (towards negative angles). According to

the reciprocity theorem, the two polarizations are routed towards the two input/output ports 10a and 10b in a more efficient manner with respect to the depointing effect. In fact, the proposed solution allows to bring back the beam depointing of the two bands to the same direction (in the previous example, to the same negative angles). The depointing is not cancelled out, but, by carefully designing the antenna 4, and the single-ridge waveguide 13 in particular, it is possible to keep it as low as $\pm 2^\circ$ on the whole, with respect to the RX or TX central frequency, attaining an acceptable antenna gain reduction.

[0049] Finally, it is clear that numerous variations and modifications may be made to the array antenna described and illustrated herein, all falling within the scope of the invention as defined in the attached claims.

[0050] For example, it is possible to devise slots 11 having different forms. In particular, in case of tapered slots, their tips 24 may have different angles and/or may extend beyond the broadwall axis A. In general, the slot shape may be optimized based on the performances of the antenna in terms of bandwidth or crosspolarization purity. For example, the slot shape may have different length and/or thickness.

[0051] Moreover, the disclosed geometry is not limited to single-ridge waveguides.

[0052] Furthermore, the present antenna may be advantageously incorporated into an antenna system 35, further comprising switching means to route feeding signals towards the proper input/output port 10a, 10b, filters or circulators for properly selecting the received signal from the transmitted signal at the input/output ports, as well as known components suited to form a transmitting and receiving system. For example, Figure 3a shows a switch 30 connecting a system input 31 to either the first or the second input/output port 10a, 10b.

[0053] Figure 6 shows another antenna system 40 incorporating the antenna 4.

[0054] The antenna system 40 of Figure 6 comprises an input port 41, a n-way power splitter 42 connected to the input port 41 and having n output ports, each connected with a respective TX chain 43. The antenna system 40 further comprises n waveguides 13, each connected to a respective TX chain 43, and n RX chains 44, each connected to a respective waveguide 13. The RX chains 44 are connected to a n-way power combiner 45, in turn connected to an output port 46 of the antenna system 40.

[0055] More in detail, and referring to Figure 7a, each TX chain 43 of the antenna system 40 comprises, cascade-connected to each other, a phase-shifter 7, a power amplifier 50, a microstrip waveguide transition 51, and a RX reject filter 52. The power amplifier 50 may be a solid state power amplifier; the RX reject filter 52 of course has the aim of blocking the RX received signal.

[0056] Referring to Figure 7b, each RX chain 44 comprises, cascade-connected to each other, a TX reject filter 53, a microstrip waveguide transition 54, a low noise amplifier 55, and a phase shifter 7. The TX reject filter

52 here has the aim of blocking the TX signal.

[0057] In Figure 6, the number n of waveguides 13, as well as the implementation of the blocks of the TX chains 43 and the RX chains 44, may be optimized according to the requirements of the antenna system 40, e.g. its technical specifications in terms of Effective Isotropic Radiated Power (EIRP), or the like.

10 Claims

1. An antenna (4) comprising a waveguide (13) having a top broadwall (12) and a plurality of radiant elements (5) formed on said top broadwall (12) and configured to radiate and receive circularly polarized waves, the broadwall having a broadwall axis (A) extending longitudinally thereto, wherein each radiant element (5) comprises two slots (11a, 11b) arranged at 90° to each other, the slots (11a, 11b) of each radiant element being non-overlapping, extending on opposite sides with respect of the broadwall axis (A) and being spaced apart from each other by a mutual distance comprised in a range of $\lambda_g/4 \pm 20\%$, wherein λ_g is a nominal guide wavelength; **characterized in that** said radiant elements form groups of radiant elements, each group including a first and a second radiant elements (5a, 5b) arranged specularly to each other with respect to an axis perpendicular to the broadwall axis (A).
2. An antenna according to claim 1, wherein said waveguide (13) is a single-ridge waveguide.
3. An antenna according to claim 1 or 2, wherein the slots (11a, 11b) of each radiant element (5) have elongated shapes defining longitudinal axes (23) extending at $\pm 45^\circ \pm 20\%$ with respect to said broadwall axis (A).
4. An antenna according to any of claims 1-3, wherein the slots (11a, 11b) of each radiant (5) element are congruent to each other.
5. An antenna according to any of the preceding claims, wherein said slots (11a, 11b) are tapered towards said broadwall axis (A).
6. An antenna according to claim 5, wherein said slots (11a, 11b) have each a tip, the tips of said slots (11a, 11b) being aligned along said broadwall axis (A).
7. An antenna according to any of the preceding claims, wherein each group of radiant elements (5) is spaced from adjacent groups by distances (d3) multiple of the nominal guide wavelength λ_g .
8. An antenna according to any of the preceding claims, wherein the radiant elements (5a, 5b) of each radiant

element group are spaced by $\lambda_g/2$.

9. An antenna according to any of the preceding claims, comprising a plurality of further waveguides (13) arranged parallel to each other. 5
10. An antenna according to any of the preceding claims, wherein the waveguide (13) has a first and a second input/output ports (10a, 10b) configured to be selectively fed with a TX signal, the antenna emitting a circularly polarized radiation having a first circular polarization when being fed with said TX signal from said first input/output port (10a) and emitting a circularly polarized radiation having a second circular polarization when being fed with said TX signal from said second input/output port (10b). 10 15
11. An antenna according to claim 10, further comprising switching means (30) having an input (31), a first output connected to said first input/output port (10a) and a second output connected to said second input/output port (10b). 20
12. An antenna according to claim 10, further comprising: 25
 - a n-way power splitter (42), having a plurality of output ports,
 - a plurality of TX chains (43), each TX chain being connected with a respective output port of the n-way power splitter (42), each waveguide of said plurality being connected to a respective TX chain (43), 30
 - a plurality of RX chains (44), each of RX chain being connected to a respective waveguide (13), and 35
 - an n-way power combiner (45), having a plurality of input ports, each input port being connected to a respective RX chain (44). 40
13. An antenna according to claim 12, wherein each TX chain (43) comprises, cascade-connected to each other, a phase-shifter (7), a power amplifier (50), a microstrip waveguide transition (51), and an RX reject filter (52). 45
14. An antenna according to claim 12 or 13, wherein each RX chain comprises, cascade-connected to each other, a TX reject filter (53), a microstrip waveguide transition (54), a low noise amplifier (55), and a phase shifter (7). 50
15. A method for operating an antenna (4) comprising a waveguide (13) according to any of claims 1-11, the waveguide (13) having a first and a second input/output ports (10a, 10b), the method comprising: 55
 - feeding a TX signal on either the first (10a) or

the second input/output port (10b),

- emitting a circularly polarized radiation having a first circular polarization when feeding said TX signal from said first input/output port (10a) and emitting a circularly polarized radiation having a second circular polarization when feeding said TX signal from said second input/output port (10b).

16. A method according to claim 15, wherein a transmission signal has a first or a second band, said first and second bands being arranged on opposite sides with respect to a nominal guide wavelength, wherein the TX signal is selectively supplied to the first (10a) or the second input/output port (10b) depending on TX signal having the first or second band.
17. A method according to claim 15 or 16, comprising receiving a circularly polarized RX signal having an RX signal polarization and detecting the RX signal from the first (10a) or the second input/output port (10b) depending on the RX signal polarization.
18. A method according to claim 15, said TX signal having a first band and being fed at a first input port (10a), further comprising receiving a circularly polarized RX signal, said circularly polarized RX signal having a second circular polarization, opposite to the first circular polarization, and a second band, said first band of the TX signal and said second band of the RX signal being arranged on opposite sides with respect to a nominal guide wavelength, the method further comprising detecting the RX signal from the second input/output port (10b).
19. A method according to claim 18, wherein said first band of said TX signal and said second band of said RX signal are symmetric with respect to the nominal guide wavelength, said TX signal being emitted along a first direction and said RX signal being received from a second direction, thereby said first direction and said second direction are parallel and any depointing effect is reduced.

Patentansprüche

1. Antenne (4), die einen Wellenleiter (13) mit einer oberen Querwand (12) und mehreren Strahlerelementen (5), die auf der oberen Querwand (12) gebildet und konfiguriert sind, um zirkular polarisierte Wellen auszustrahlen und zu empfangen, umfasst, wobei die Querwand eine Querwandachse (A) besitzt, die sich längs dazu erstreckt, wobei jedes Strahlerelement (5) zwei Schlitze (11a, 11b) umfasst, die unter 90° zueinander angeordnet sind, wobei die Schlitze (11a, 11b) eines jeden Strahlerelements nicht überdeckend sind, und sich auf gegen-

überliegenden Seiten in Bezug auf die Querwandachse (A) erstrecken und voneinander um einen gegenseitigen Abstand, der in einem Bereich von $\lambda_g/4 \pm 20\%$ enthalten ist, beabstandet sind, wobei λ_g eine nominale Leiterwellenlänge ist;

dadurch gekennzeichnet, dass die Strahlerelemente Gruppen von Strahlerelementen bilden, wobei jede Gruppe ein erstes und ein zweites strahlendes Element (5a, 5b) enthält, die in Bezug auf eine zu der Querwandachse (A) senkrechte Achse spiegelsymmetrisch zueinander angeordnet sind.

2. Antenne nach Anspruch 1, wobei der Wellenleiter (13) ein Einzelrippenwellenleiter ist.
3. Antenne nach Anspruch 1 oder 2, wobei die Schlitze (11a, 11b) jedes Strahlerelements (5) langgestreckte Formen besitzen, die Längsachsen (23) definieren, die sich in $\pm 45^\circ \pm 20\%$ in Bezug auf die Querwandachse (A) erstrecken.
4. Antenne nach einem der Ansprüche 1-3, wobei die Schlitze (11a, 11b) jedes Strahlerelements (5) kongruent zueinander sind.
5. Antenne nach einem der vorhergehenden Ansprüche, wobei die Schlitze (11a, 11b) in Richtung der Querwandachse (A) spitz zulaufend sind.
6. Antenne nach Anspruch 5, wobei jeder der Schlitze (11a, 11b) eine Spitze besitzt, wobei die Spitzen der Schlitze (11a, 11b) entlang der Querwandachse (A) ausgerichtet sind.
7. Antenne nach einem der vorhergehenden Ansprüche, wobei jede Gruppe von Strahlerelementen (5) von benachbarten Gruppen um Abstände (d3) beabstandet ist, die Vielfache der nominalen Leiterwellenlänge λ_g sind.
8. Antenne nach einem der vorhergehenden Ansprüche, wobei die Strahlerelemente (5a, 5b) jeder Gruppe von Strahlerelementen um $\lambda_g/2$ beabstandet sind.
9. Antenne nach einem der vorhergehenden Ansprüche, die mehrere weitere Wellenleiter (13) umfasst, die parallel zueinander angeordnet sind.
10. Antenne nach einem der vorhergehenden Ansprüche, wobei der Wellenleiter (13) eine erste und eine zweite Eingangs-/Ausgangsöffnung (10a, 10b) besitzt, die konfiguriert sind, wahlweise mit einem TX-Signal gespeist zu werden, wobei die Antenne eine zirkular polarisierte Strahlung mit einer ersten zirkularen Polarisierung aussendet, wenn sie mit dem TX-Signal von der ersten Eingangs-/Ausgangsöffnung (10a) gespeist wird, und eine zirkular polarisierte Strahlung mit einer zweiten zirkularen Polarisierung

aussendet, wenn sie mit dem TX-Signal von der zweiten Eingangs-/Ausgangsöffnung (10b) gespeist wird.

11. Antenne nach Anspruch 10, die ferner Schaltmittel (30) mit einem Eingang (31), einem ersten Ausgang, der mit der ersten Eingangs-/Ausgangsöffnung (10a) verbunden ist, und einem zweiten Ausgang, der mit der zweiten Eingangs-/Ausgangsöffnung (10b) verbunden ist, umfasst.
12. Antenne nach Anspruch 10, die ferner Folgendes umfasst:
 - einen n-Weg-Leistungssplitter (42) mit mehreren Ausgangsöffnungen,
 - mehrere TX-Ketten (43), wobei jede TX-Kette mit einer entsprechenden Ausgangsöffnung des n-Weg-Leistungssplitters (42) verbunden ist, wobei jeder Wellenleiter der mehreren mit einer entsprechenden TX-Kette (43) verbunden ist,
 - mehrere RX-Ketten (44), wobei jede RX-Kette mit einem entsprechenden Wellenleiter (13) verbunden ist, und
 - einen n-Weg-Leistungskombinierer (45) mit mehreren Eingangsöffnungen, wobei jede Eingangsöffnung mit einer entsprechenden RX-Kette (44) verbunden ist.
13. Antenne nach Anspruch 12, wobei jede TX-Kette (43) in Kaskadenschaltung zueinander einen Phasenschieber (7), einen Leistungsverstärker (50), einen Mikrostreifenleiter-Wellenleiter-Übergang (51) und ein RX-Unterdrückungsfilter (52) umfasst.
14. Antenne nach Anspruch 12 oder 13, wobei jede RX-Kette in Kaskadenschaltung zueinander umfasst: ein TX-Unterdrückungsfilter (53), einen Mikrostreifenleiter-Wellenleiter-Übergang (54), einen rauscharmen Verstärker (55) und einen Phasenschieber (7).
15. Verfahren zum Betreiben einer Antenne (4), die einen Wellenleiter (13) umfasst, nach einem der Ansprüche 1-11, wobei der Wellenleiter (13) eine erste und eine zweite Eingangs-/Ausgangsöffnung (10a, 10b) besitzt, wobei das Verfahren Folgendes umfasst:
 - Einspeisen eines TX-Signals in entweder die erste (10a) oder die zweite Eingangs-/Ausgangsöffnung (10b),
 - Aussenden einer zirkular polarisierten Strahlung mit einer ersten zirkularen Polarisierung, wenn das TX-Signal von der ersten Eingangs-/Ausgangsöffnung (10a) eingespeist wird, und Aussenden einer zirkular polarisierten

Strahlung mit einer zweiten zirkularen Polarisierung, wenn das TX-Signal von der zweiten Eingangs-/Ausgangsöffnung (10b) eingespeist wird.

16. Verfahren nach Anspruch 15, wobei ein Übertragungssignal ein erstes oder ein zweite Band besitzt, wobei das erste und das zweite Band auf gegenüberliegenden Seiten in Bezug auf eine nominale Leiterwellenlänge angeordnet sind, wobei das TX-Signal abhängig davon, ob das TX-Signal das erste oder das zweite Band besitzt, wahlweise der ersten (10a) oder der zweiten Eingangs-/Ausgangsöffnung (10b) zugeführt wird.
17. Verfahren nach Anspruch 15 oder 16, das umfasst, ein zirkular polarisiertes RX-Signal mit einer RX-Signalpolarisierung zu empfangen und das RX-Signal abhängig von der RX-Signalpolarisierung von der ersten (10a) oder der zweiten Eingangs-/Ausgangsöffnung (10b) zu detektieren.
18. Verfahren nach Anspruch 15, wobei das TX-Signal ein erstes Band besitzt und an der ersten Eingangsöffnung (10a) eingespeist wird, das ferner umfasst, ein zirkular polarisiertes RX-Signal zu empfangen, wobei das zirkular polarisierte RX-Signal eine zweite zirkulare Polarisierung entgegengesetzt zu der ersten zirkularen Polarisierung besitzt, und ein zweites Band, wobei das erste Band des TX-Signals und das zweite Band des RX-Signals in Bezug auf eine nominale Leiterwellenlänge auf gegenüberliegenden Seiten angeordnet sind, wobei das Verfahren ferner umfasst, das RX-Signal von der zweiten Eingangs-/Ausgangsöffnung (10b) zu detektieren.
19. Verfahren nach Anspruch 18, wobei das erste Band des TX-Signals und das zweite Band des RX-Signals in Bezug auf die nominale Leiterwellenlänge symmetrisch sind, wobei das TX-Signal entlang einer ersten Richtung ausgesendet wird und das RX-Signal von einer zweiten Richtung empfangen wird, wodurch die erste Richtung und die zweite Richtung parallel sind und jegliche Fehlausrichtungseffekte verringert werden.

Revendications

1. Antenne (4) comprenant un guide d'onde (13) ayant une paroi large supérieure (12) et une pluralité d'éléments rayonnants (5) formée sur ladite paroi large supérieure (12) et configurée pour rayonner et recevoir des ondes à polarisation circulaire, la paroi large ayant un axe de paroi large (A) s'étendant longitudinalement vers celle-ci, dans laquelle chaque élément rayonnant (5) comprend deux fentes (11a, 11b) agencées à 90° l'une par rapport à l'autre, les fentes

(11a, 11b) de chaque élément rayonnant étant non chevauchantes, s'étendant sur des côtés opposés par rapport à l'axe de paroi large (A) et étant espacées l'une de l'autre d'une distance mutuelle comprise dans une plage de $\lambda_g/4 \pm 20\%$, dans lequel λ_g est une longueur d'onde de guide nominale ; **caractérisée en ce que** lesdits éléments rayonnants forment des groupes d'éléments rayonnants, chaque groupe incluant des premier et second éléments rayonnants (5a, 5b) agencés spéculairement les uns par rapport aux autres par rapport à un axe perpendiculaire à l'axe de paroi large (A).

2. Antenne selon la revendication 1, dans laquelle ledit guide d'onde (13) est un guide d'onde à nervure unique.
3. Antenne selon la revendication 1 ou 2, dans laquelle les fentes (11a, 11b) de chaque élément rayonnant (5) ont des formes allongées définissant des axes longitudinaux (23) s'étendant à $\pm 45^\circ \pm 20\%$ par rapport audit axe de paroi large (A).
4. Antenne selon l'une quelconque des revendications 1 à 3, dans laquelle les fentes (11a, 11b) de chaque élément rayonnant (5) sont congruentes les unes par rapport aux autres.
5. Antenne selon l'une quelconque des revendications précédentes, dans laquelle lesdites fentes (11a, 11b) sont effilées vers ledit axe de paroi large (A).
6. Antenne selon la revendication 5, dans laquelle lesdites fentes (11a, 11b) ont chacune une extrémité, les extrémités desdites fentes (11a, 11b) étant alignées le long dudit axe de paroi large (A).
7. Antenne selon l'une quelconque des revendications précédentes, dans laquelle chaque groupe d'éléments rayonnants (5) est espacé des groupes adjacents de distances (d3) multiples de la longueur d'onde de guide nominale λ_g .
8. Antenne selon l'une quelconque des revendications précédentes, dans laquelle les éléments rayonnants (5a, 5b) de chaque groupe d'éléments rayonnants sont espacés de $\lambda_g/2$.
9. Antenne selon l'une quelconque des revendications précédentes, comprenant une pluralité de guides d'onde supplémentaires (13) agencés parallèlement les uns par rapport aux autres.
10. Antenne selon l'une quelconque des revendications précédentes, dans laquelle le guide d'onde (13) a des premier et second orifices d'entrée/de sortie (10a, 10b) configurés pour être sélectivement alimentés en un signal TX, l'antenne émettant un

rayonnement à polarisation circulaire ayant une première polarisation circulaire lorsqu'elle est alimentée en ledit signal TX en provenance du premier orifice d'entrée/de sortie (10a) et émettant un rayonnement à polarisation circulaire ayant une seconde polarisation circulaire lorsqu'elle est alimentée en ledit signal TX en provenance dudit second orifice d'entrée/de sortie (10b).

11. Antenne selon la revendication 10, comprenant en outre un moyen de commutation (30) ayant une entrée (31), une première sortie raccordée audit premier orifice d'entrée/de sortie (10a) et une seconde sortie raccordée audit second orifice d'entrée/de sortie (10b).

12. Antenne selon la revendication 10, comprenant en outre :

- un diviseur de puissance n-voie (42), ayant une pluralité d'orifices de sortie,
- une pluralité de chaînes TX (43), chaque chaîne TX étant connectée à un orifice de sortie respectif du diviseur de puissance n-voie (42), chaque guide d'onde de ladite pluralité étant connecté à une chaîne TX (43) respective,
- une pluralité de chaînes RX (44), chacune des chaînes RX étant connectée à un guide d'onde respectif (13), et
- un combinateur de puissance n-voie (45), ayant une pluralité d'orifices d'entrée, chaque orifice d'entrée étant connecté à une chaîne RX (44) respective.

13. Antenne selon la revendication 12, dans laquelle chaque chaîne TX (43) comprend, connectés en cascade les uns avec les autres, un déphaseur (7), un amplificateur de puissance (50), une transition de microruban-guide d'onde (51), et un filtre de rejet RX (52).

14. Antenne selon la revendication 12 ou 13, dans laquelle chaque chaîne RX comprend, connectés en cascade les uns avec les autres, un filtre de rejet TX (53), une transition micro-ruban-guide d'onde (54), un amplificateur à faible bruit (55), et un déphaseur (7).

15. Méthode d'exploitation d'une antenne (4) comprenant un guide d'onde (13) selon l'une quelconque des revendications 1 à 11, le guide d'onde (13) ayant des premier et second orifices d'entrée/de sortie (10a, 10b), la méthode comprenant :

- l'alimentation en un signal TX sur soit le premier (10a) soit le second (10b) orifice d'entrée/de sortie,
- l'émission d'un rayonnement à polarisation cir-

culaire ayant une première polarisation circulaire lors de l'alimentation en ledit signal TX en provenance dudit premier orifice d'entrée/de sortie (10a) et l'émission d'un rayonnement à polarisation circulaire ayant une seconde polarisation circulaire lors de l'alimentation en ledit signal TX en provenance dudit second orifice d'entrée/de sortie (10b).

16. Méthode selon la revendication 15, dans laquelle un signal de transmission a une première et une seconde bande, lesdites première et seconde bandes étant agencées sur des côtés opposés par rapport à une longueur d'onde de guide nominale, dans laquelle le signal TX est sélectivement fourni au premier (10a) ou au second (10b) orifice d'entrée/de sortie en fonction d'un signal TX ayant la première ou la seconde bande.

17. Méthode selon la revendication 15 ou 16, comprenant la réception d'un signal RX à polarisation circulaire ayant une polarisation de signal RX et la détection du signal RX en provenance du premier (10a) et du second (10b) orifice d'entrée/de sortie en fonction de la polarisation de signal RX.

18. Méthode selon la revendication 15, ledit signal TX ayant une première bande et étant alimenté au niveau d'un premier orifice d'entrée (10a), comprenant en outre la réception d'un signal RX à polarisation circulaire, ledit signal RX à polarisation circulaire ayant une seconde polarisation circulaire, opposée à la première polarisation circulaire, et une seconde bande, ladite première bande du signal TX et ladite seconde bande du signal RX étant agencées sur des côtés opposés par rapport à la longueur d'onde de guide nominale, la méthode comprenant en outre la détection du signal RX en provenance du signal orifice d'entrée/de sortie (10b).

19. Méthode selon la revendication 18, dans laquelle ladite première bande dudit signal TX et ladite seconde bande dudit signal RX sont symétriques par rapport à la longueur d'onde de guide nominale, ledit signal TX étant émis le long d'une première direction et ledit signal RX étant reçu en provenance d'une seconde direction, moyennant quoi ladite première direction et ladite seconde direction sont parallèles et tout effet de dépointage est réduit.

FIG. 1

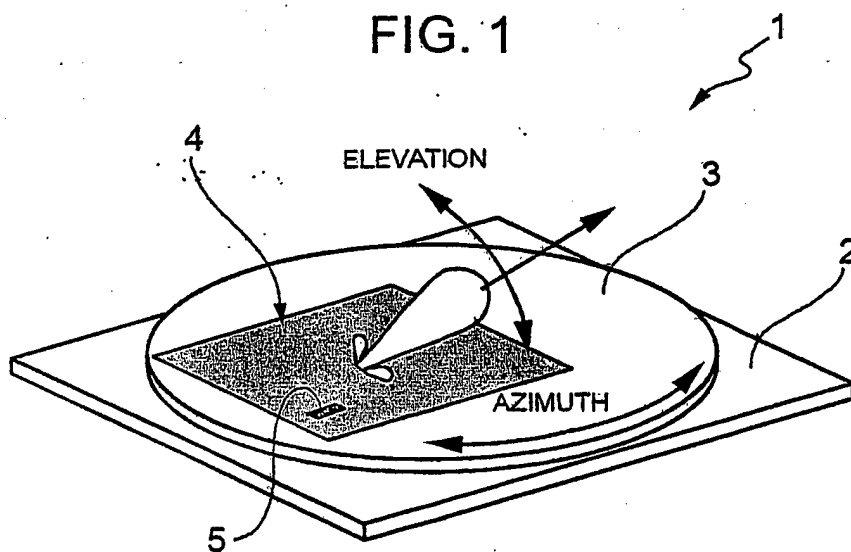
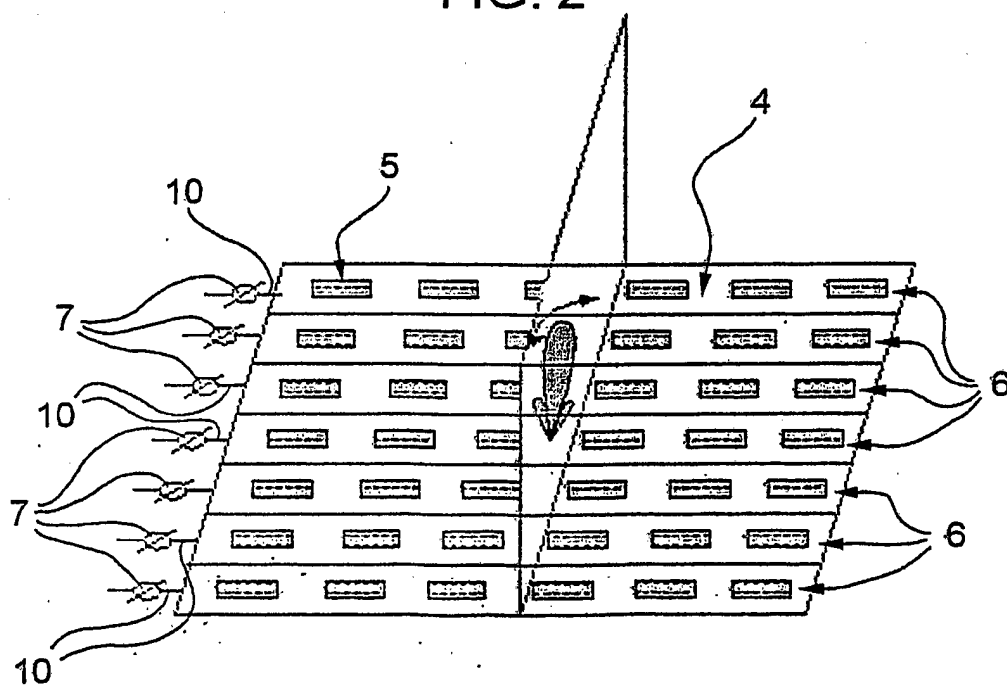


FIG. 2



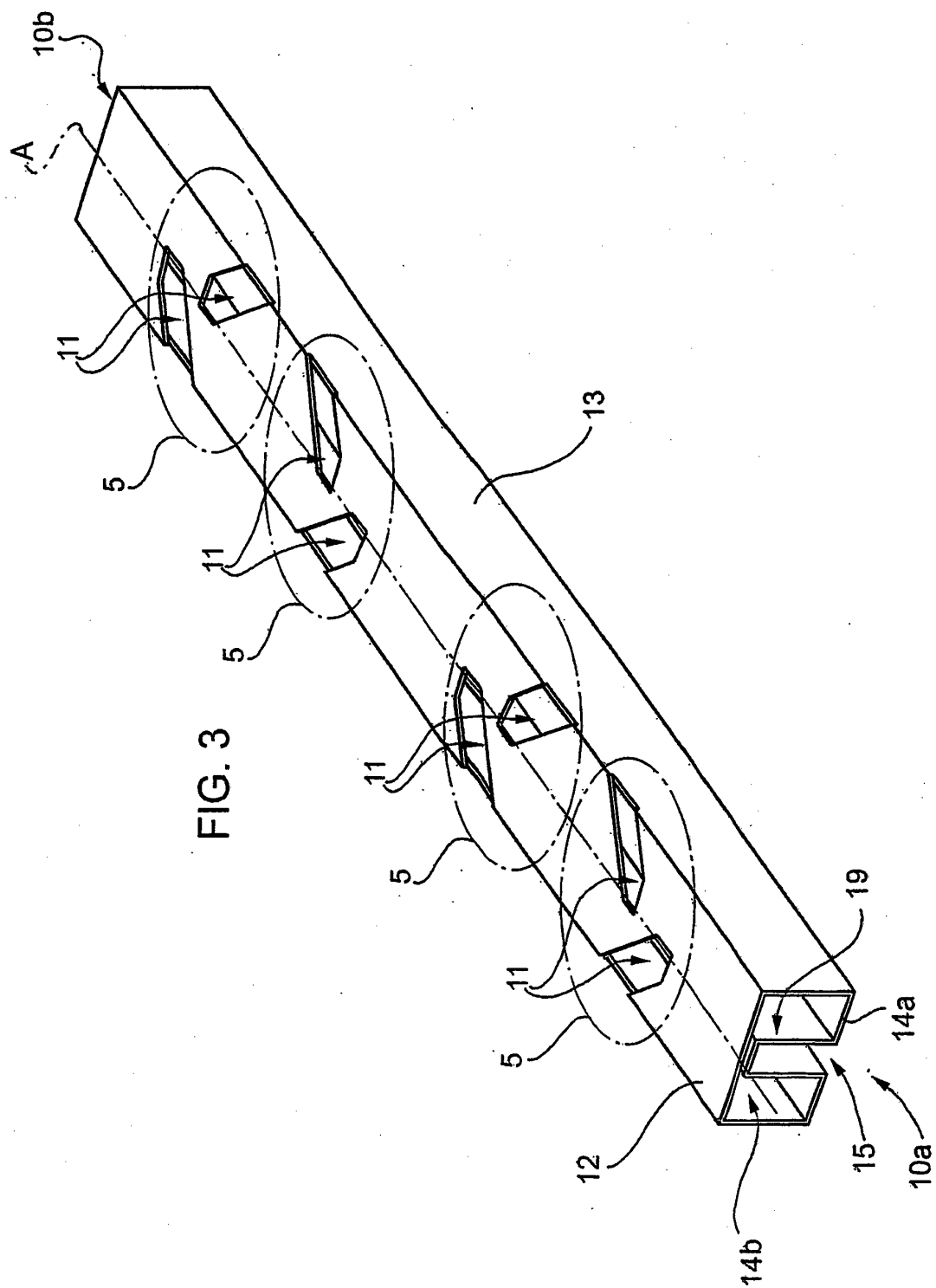
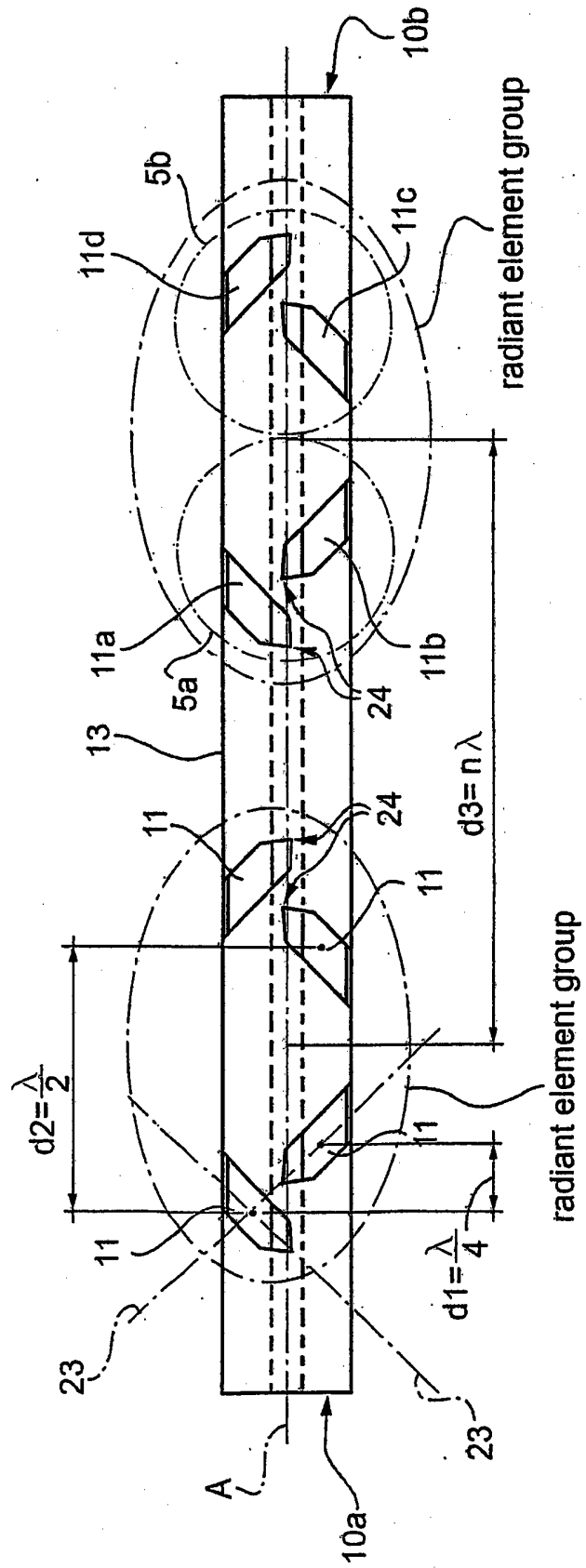
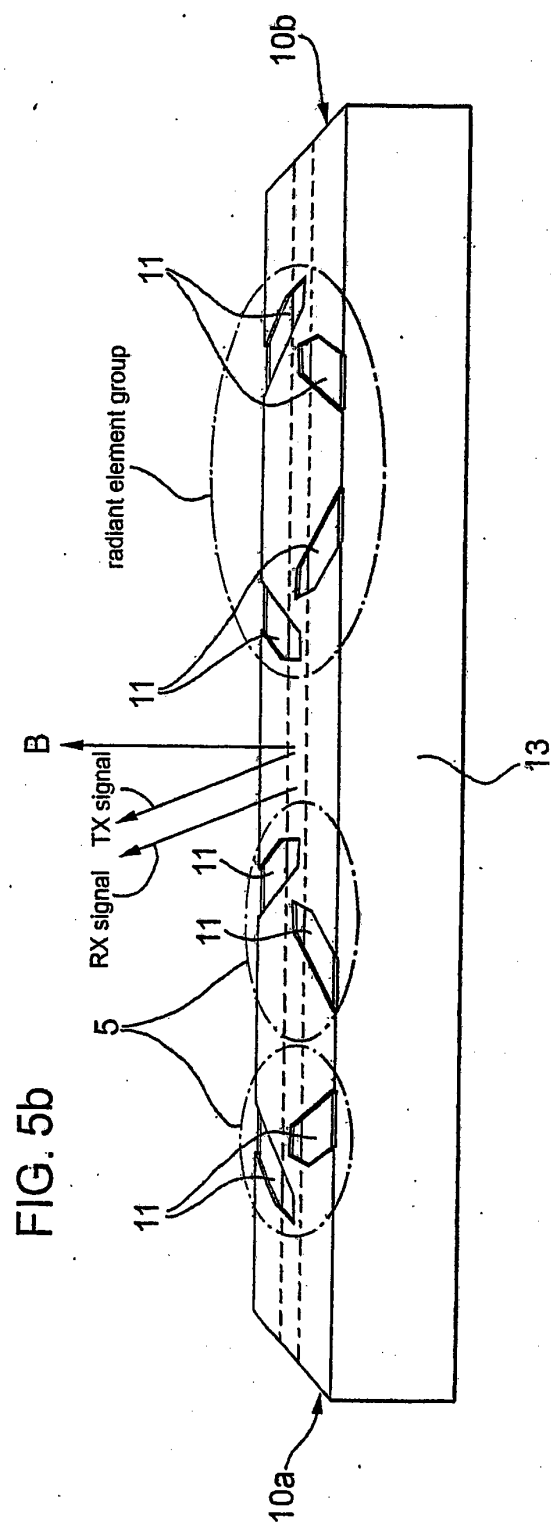
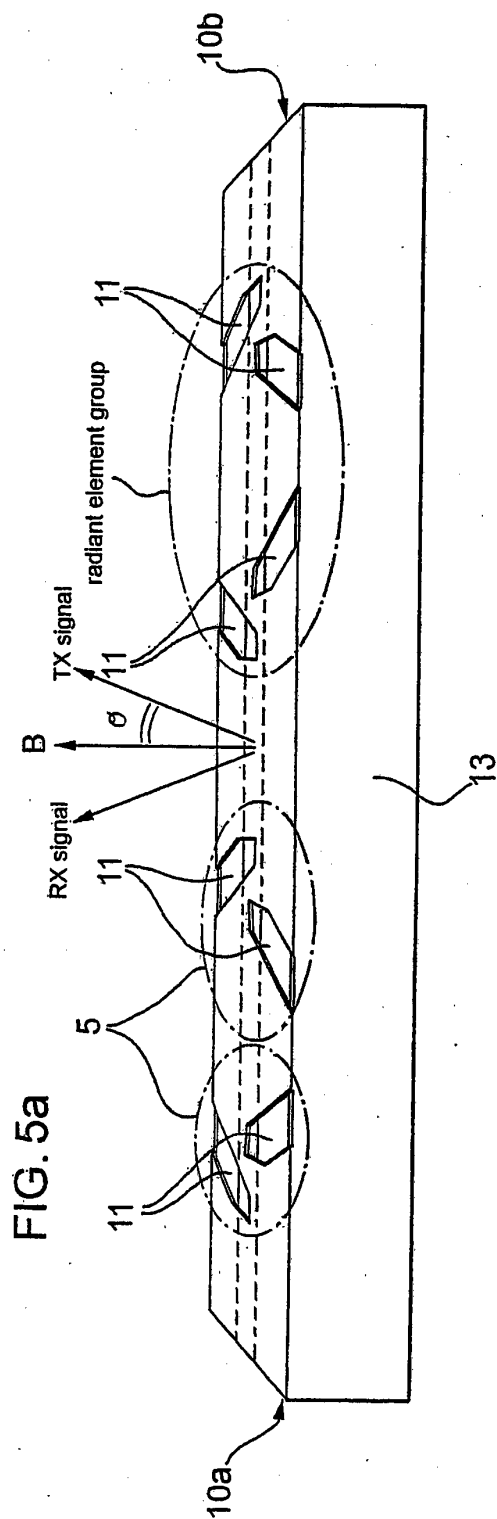


FIG. 3

FIG. 4





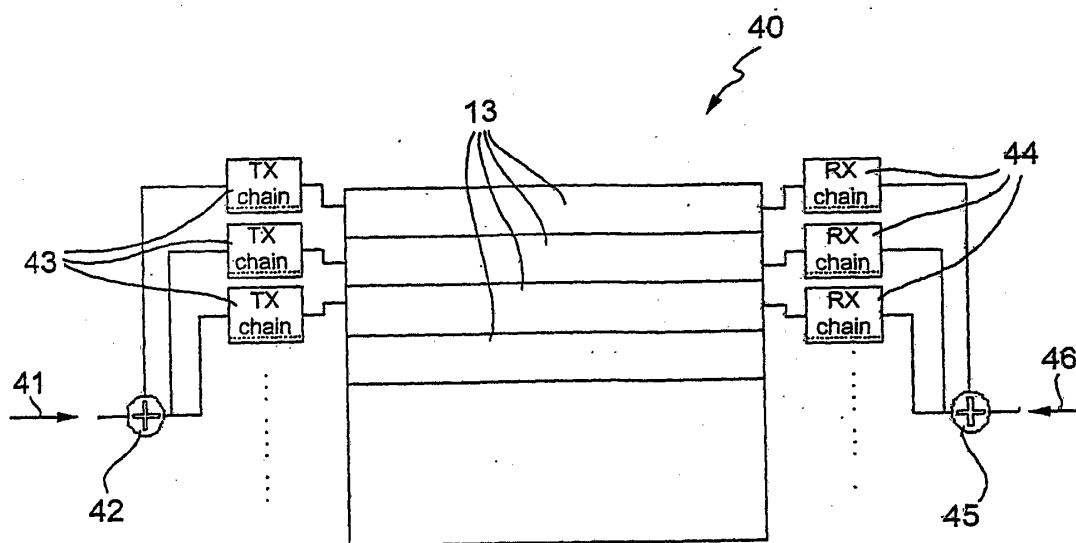


FIG. 6

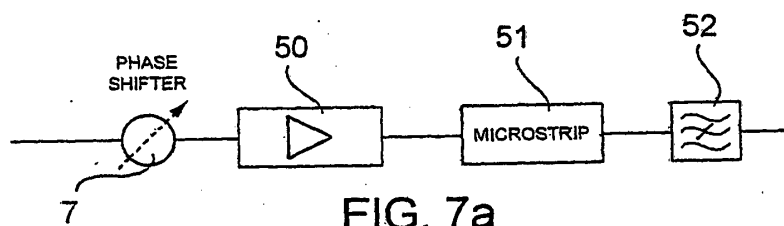


FIG. 7a

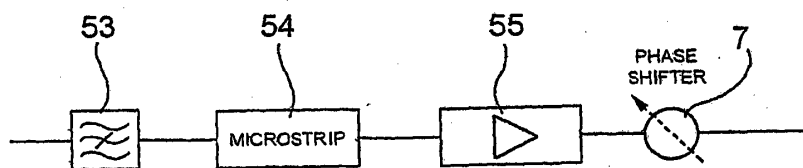


FIG. 7b

REFERENCES CITED IN THE DESCRIPTION

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