

Steerable antenna and method for controlling said steerable antenna

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RÉSUMÉ

Steerable antenna (1) comprising: a first antenna group comprising M antenna elements (5), a second antenna group comprising N antenna elements (5), said N antenna elements (5) surrounding the M antenna elements (5) of first antenna group, switching means (100) coupled to the N antenna elements (5) of second antenna group and a controller (110) programmed for sequentially switching to be active and at different times successive antenna subgroups of second antenna group, while switching at same different times other antenna elements (5) of same second antenna group to be passively terminated in different possible loads. The steerable antenna (1) also comprises L inner termination groups (215) and L inner termination switches (205), $1 \leq L \leq M$, allowing modifying the termination loads of the antenna elements (5) of first antenna group.

DESCRIPTION (Le texte OCR peut contenir des erreurs.)

Steerable antenna and method for controlling said steerable antenna

Field of the invention

[0001] According to a first aspect, the invention relates to a steerable antenna. According to a second aspect, the invention relates to a method for controlling a steerable antenna.

Description of prior art

[0002] Antennas are used in a wide variety of applications both as transmitters and receivers of electromagnetic energy. One important consideration in many of these applications is the directivity of the antenna: it is generally desirable to maximise the directional properties of the antenna. Directivity is known by the one skilled in the art. Directivity measures the power density that an antenna radiates in the direction of its strongest emission, normalized with respect to the power density radiated by an ideal isotropic radiator that emits uniformly in all directions and that radiates the same total power. Directivity is generally expressed in decibels over isotropic, dBi.

[0003] Phased array antennas are directive and comprise an array with several antenna elements. Phased array antennas allow producing a non- isotropic radiation pattern that can be scanned in different directions. Phased array antennas use antenna elements that are all active all the time. Phased array antennas thus require providing sophisticated controlled feeds to the various antenna elements. Therefore, phased array antennas have a complex configuration and are costly to manufacture. Moreover, they are heavy and bulky. These drawbacks are even more apparent when the number of active antenna elements is large.

[0004] ESPAR (Electronically Steerable Passive Array Radiator) antennas comprise one active antenna element and several passive (or parasitic) antenna elements located on a circumference of a circle around the active antenna element. Such an antenna is notably described in EP1355377A2 where a controller changes the directivity of the antenna by changing the reactive loading (inductor or capacitor) terminating each passive antenna element. In EP1355377A2, the voltage applied to each voltage-tunable capacitor connected to the passive antenna elements is varied.

[0005] ESPAR antennas do require a less complex feeding network and are cheaper than phased array antennas. However, the directivity of the ESPAR antennas is limited. There is therefore a need to provide a steerable antenna that presents a higher directivity than an ESPAR antenna.

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REVENDECATIONS (Le texte OCR peut contenir des erreurs.)

Claims

1 . Steerable antenna (1) comprising:

- a first antenna group comprising M antenna elements (5), $M > 1$;
 - a second antenna group comprising N antenna elements (5), $N > 1$, said N antenna elements (5) being arranged along a closed outer contour line (21) and surrounding the M antenna elements (5) of the first antenna group;
- characterized in that :
- said steerable antenna (1) further comprises switching means (100) coupled to the N antenna elements (5) of the second antenna group; in that
 - said steerable antenna (1) further comprises a controller (1 10) programmed for controlling said switching means (100) for switching to be active at different times one different antenna subgroup comprising Na antenna elements (5) of the second antenna group, $1 < Na \leq N-1$, while switching to be passive at same different times N-Na other antenna elements (5) of the second antenna group; in that
 - said steerable antenna (1) further comprises L inner termination groups (215), $1 < L < M$, each of them comprising a plurality of different termination loads (220); in that
 - said switching means (100) comprise L inner termination switches (205), each of them being connected in between one antenna element (5) of said first antenna group and the different termination loads (220) of one different of said L inner termination groups (215); and in that
 - said controller (1 10) is also programmed for controlling said L inner termination switches (205) for connecting and disconnecting each of L antenna element (5) of first antenna group to and from the termination loads (220) of one different inner termination group (215).

2. Steerable antenna (1) according to claim 1 characterized in that said controller (1 10) is programmed and said termination loads (220) of the L inner termination groups (215) are chosen for imposing a symmetry in termination load of different antenna elements (5) of first antenna group with respect to a main radiation lobe of said steerable antenna (1).

[0006] According to a first aspect, it is an object of the invention to provide an antenna that presents a higher directivity than the one of an ESPAR antenna. To this end, the invention relates to a steerable antenna comprising:

- a first antenna group comprising M antenna element, $M > 1$;
 - a second antenna group comprising N antenna elements, $N > 1$, said N antenna elements being arranged along a closed outer contour line and surrounding the M antenna elements of the first antenna group.
- The steerable antenna of the invention is characterized in that:
- said steerable antenna comprises switching means coupled to the N antenna elements of the second antenna group; in that
 - said steerable antenna comprises a controller programmed for controlling said switching means for switching to be active at different times one different antenna subgroup comprising N_a antenna elements of the second antenna group, $1 < N_a < N-1$, while switching to be passive at same different times $N-N_a$ other antenna elements of the second antenna group; in that
 - said steerable antenna further comprises L inner termination groups, $1 < L \leq M$, each of them comprising a plurality of (at least two) different termination loads; in that
 - said switching means comprise L inner termination switches, each of them being connected in between one antenna element of said first antenna group and the different termination loads of one different of said L inner termination groups; and in that
 - said controller is also programmed for controlling said L inner termination switches for connecting and disconnecting each of L antenna elements of first antenna group to and from the termination loads of one different inner termination group.

So, the controller for controlling the switching means is programmed such that, in use, at least one antenna element of the second antenna group is switched to be active at different times while the other antenna element(s) of the second antenna group is (are) switched to be passive at same different times. This allows having a radiation pattern that can rotate by a number of angles around a given axis. Preferably, the controller is also programmed for connecting and disconnecting at different times said $N-N_a$ other passive antenna elements of second antenna group to and from different termination loads.

[0007] Contrary to an ESPAR antenna, N_a antenna elements of the second antenna group are active at each time t when the steerable antenna of the invention is in operation. The other $N-N_a$ antenna elements of the second antenna group are passive (hence in a parasitic state) when the N_a antenna elements of the second antenna group are active. In an ESPAR antenna, the second antenna group only comprises passive antenna elements. In the steerable antenna according to the invention, the M antenna elements of the first antenna group collectively play the role of an intelligent reflector that leads to an increase in directivity of the steerable antenna. In other words, the M antenna elements of the first antenna group provide a collective scattering effect.

[0008] The antenna of the invention also comprises L inner termination groups, $1 < L < M$, each of them comprising a plurality of termination loads, L inner termination switches connected as explained above, and the controller for controlling said inner termination switches as exposed above. This allows modulating or adapting the termination loads of the antenna elements of first antenna group for further increasing the directivity of the steerable antenna. In particular, the termination loads of L antenna elements of first antenna group are modulated depending on the direction of main radiation lobe (desired direction of maximum radiation). Finally, for these different reasons, the steerable antenna of the invention allows obtaining a higher directivity with respect to the one of an ESPAR antenna. [0009] When several antenna elements of the second antenna group are switched at different times to be active together (that means $N_a > 1$), the directivity is still higher: the use of such $N_a > 1$ active antenna elements of the second antenna group, accompanied by $N-N_a$ passive antenna elements of same second antenna group widens the active zone of second antenna group and so further contributes in obtaining a higher directivity.

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3. Steerable antenna (1) according to any of previous claims characterized in that:

- said steerable antenna (1) further comprises K outer termination groups (210), $1 < K \leq N$, each of them comprising a plurality of different termination loads (220); in that
- said switching means (100) comprise K outer termination switches (200) each of them being connected in between one antenna element (5) of said second antenna group and the different termination loads (220) of one different outer termination group (210); and in that
- said controller (1 10) is also programmed for controlling the K outer termination switches (200) for connecting and disconnecting each of K antenna elements (5) of the second antenna group to and from the termination loads (220) of one different outer termination group (210).

4. Steerable antenna (1) according to previous claim characterized in that said controller (1 10) is programmed and said termination loads (220) of the K outer termination groups (210) are chosen for imposing symmetry in termination load of different antenna elements (5) of second antenna group with respect to a main radiation lobe of said steerable antenna (1).

5. Steerable antenna (1) according to any of previous claims characterized in that said M antenna elements (5) of said first antenna group are all passive permanently.

6. Steerable antenna (1) according to previous claim characterized in that $L=M$, and in that the different termination loads (220) of the L inner termination groups (215) comprise non-zero real parts.

7. Steerable antenna (1) according to claim 5 or 6 characterized in that a minimal distance between one passive antenna element (5p) of first antenna X 1 group and one antenna element (5) of second antenna group is between—

$X \lambda_0$

and —, where λ_0 is a wavelength in free space of an electromagnetic radiation to be received or transmitted by the steerable antenna (1), and ϵ_r is a relative permittivity of a structure of dielectric material including the antenna elements (5).

8. Steerable antenna (1) according to any of previous claims characterized in that it comprises a total number of antenna elements (5) comprised between

10 and 32.

9. Steerable antenna (1) according to any of previous claims characterized in that said switching means (1 00) are connected to antenna elements (5) through transmission lines (70) of different lengths so as to improve directivity properties of said steerable antenna (1).

10. Steerable antenna (1) according to any of previous claims characterized in that said first and second antenna groups comprise a same number of antenna elements (5), $M=N$.

11. Steerable antenna (1) according to any of previous claims, characterized in that said closed outer contour line (21) is a circle.

[0010] The steerable antenna of the invention has other advantages. It is easy to fabricate and easy to implement, in particular in comparison with a phased array antenna. The steerable antenna of the invention is well suited for mass production and is lighter than a phased array antenna. It is also robust and has a long life cycle. Faulty components can be replaced and repairing the steerable antenna of the invention is simple. The steerable antenna of the invention is well suited in different applications of radio communications and wireless localization. The steerable antenna of the invention is a good trade-off between a phased array antenna that presents a high directivity and an ESPAR antenna that does not require sophisticated fabrication, implementation steps and that is relatively cheap. By choosing passive antenna elements for the first antenna group, one does indeed obtain a steerable antenna that is less sophisticated than a phased array antenna and almost as cheap as an ESPAR antenna, while maintaining a high directivity and a possibility to steer the beam in an azimuthal plane. With the antenna of the invention, no individual reflector element is necessary, but one could add such a reflector element. With the antenna of the invention, one does not need to use a large number of antenna elements for having good properties, in particular for having good directivity. In particular, one does not need to have a large number (larger than fifty for instance) of antenna elements for first antenna group. The antenna of the invention preferably relies on the use of only two antenna groups, even if one could use more antenna groups. As a consequence, if the different antenna elements are located in a same plane, most of the corresponding planar surface is not covered by an antenna element. The M antenna elements of first antenna group do not constitute of 'forest' of parasitic elements. Thanks to the modulation of termination loads of L antenna elements of first antenna group notably, high directivity can be obtained with few antenna elements. Hence, the antenna of the invention is not expensive and it can be small.

[0011] When the antenna elements of the second antenna group are parallel electrical monopoles, the azimuthal plane is perpendicular to these electrical monopoles. Preferably, the antenna elements of the first antenna group are protruding from a same plane. Preferably, the antenna elements of the second antenna group are located in a same plane. Preferably, the antenna elements of the first and the second antenna groups are located in a same plane.

[0012] Preferably, the steerable antenna of the invention provides maximum radiation at an elevation angle that is comprised between 10° and 40°, and more preferably close to 30°, with respect to a plane comprising the different antenna elements.

[0013] Preferably, the steerable antenna comprises a structure comprising a dielectric material and the antenna elements of first and second antenna groups are mechanically coupled to said dielectric material.

[0014] Preferably, said structure comprising a dielectric material is substantially planar. Preferably, at least one antenna element of the first antenna group is passive.

[0015] Preferably, said controller is programmed and said termination loads of the L inner termination groups are chosen for imposing a symmetry in termination load of different antenna elements of first antenna group with respect to a main radiation lobe of said steerable antenna.

With this preferred embodiment, it is possible to further increase the directivity of the antenna.

[0016] Preferably:

- said steerable antenna further comprises K outer termination groups, $1 < K < N$, each of them comprising a plurality of different termination loads;

- said switching means comprise K outer termination switches each of them being connected in between one antenna element of said second antenna group and the different termination loads of one different outer termination group; - said controller is programmed for controlling the K outer termination switches for connecting and disconnecting each of K antenna elements of the second antenna group to and from the termination loads of one different outer termination group.

With this preferred embodiment, it is possible to further increase the directivity of the antenna.

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12. Steerable antenna (1) according to any of previous claims, characterized in that said M antenna elements (5) of first antenna group are arranged along a closed inner contour line (11).

13. Steerable antenna (1) according to previous claim characterized in that said closed inner contour line (11) is a circle.

14. Steerable antenna (1) according to previous claim and according to claim 11 characterized in that said closed inner contour line (11) and said closed outer contour line (21) are concentric.

15. Steerable antenna (1) according to previous claim characterized in that it only comprises antenna elements (5) along said inner (11) and outer (21) contour lines.

16. Steerable antenna (1) according to any of previous claims, characterized in that said first antenna group comprises between three and twelve antenna elements (5), $3 < M < 12$.

17. Steerable antenna (1) according to any of previous claims, characterized in that said second antenna group comprises between three and twelve antenna elements (5), $3 < N < 12$.

18. Steerable antenna (1) according to any of previous claims characterized in that :

- said first antenna group comprises six antenna elements (5p) that are passive permanently; and in that
- said second antenna group comprises six antenna elements (5), $N = 6$.

19. Steerable antenna (1) according to previous claim, characterized in that said switching means (100) are electrically connected to the six antenna elements (5) of the second antenna group for sequentially switching to be active at different times one different antenna subgroup comprising three antenna elements (5) of the second antenna group while switching to be passive at same different times the other three antenna elements (5) of said second antenna group.

20. Steerable antenna (1) according to any of previous claims characterized in that :

- said first antenna group comprises eight antenna elements (5); and in that
- said second antenna group comprises eight antenna elements (5), $N = 8$.

21. Steerable antenna (1) according to any of previous claims characterized in that one antenna element (5) of said steerable antenna (1) is an electrical monopole.

22. Steerable antenna (1) according to previous claim characterized in that all antenna elements (5) of the steerable antenna (1) are electrical monopoles.

23. Method for controlling a steerable antenna (1), said steerable antenna (1) comprising:

- a first antenna group comprising M antenna elements (5), $M > 1$;
- a second antenna group comprising N antenna elements (5), $N > 1$, said N antenna elements (5) being disposed along a closed outer contour line 0

[0017] Preferably, said controller is programmed and said termination loads of the K outer termination groups are chosen for imposing symmetry in termination load of different antenna elements of second antenna group with respect to a main radiation lobe of said steerable antenna.

With this preferred embodiment, it is possible to further increase the directivity of the antenna.

[0018] Preferably, said M antenna elements of said first antenna group are all passive permanently. Any diffractive element known by the one skilled in the art can be used for obtaining a permanent passive antenna element.

With this preferred embodiment, the cost of fabrication of the antenna is particularly low as first antenna group only comprises permanent passive antenna elements, while maintaining high directivity.

[0019] Preferably, said switching means are connected to antenna elements through transmission lines of different lengths so as to improve directivity properties of said steerable antenna.

[0020] Preferably, $L=M$, and the different termination loads of the L inner termination groups can comprise non-zero real parts (up to the order of 20 Ohms for instance). With this preferred embodiment, it is easier to design an antenna with low-cost materials, substrates. Hence, cost of fabrication of the antenna can be further reduced by using this preferred embodiment.

[0021] Preferably, a minimal distance between one passive antenna element of first antenna group and one antenna element of second antenna

$X \times 1$

group is comprised between $\frac{\lambda_0}{2}$ and $\frac{\lambda_0}{4}$, where λ_0 is a wavelength in free

$5 \times \frac{\lambda_0}{2} \times \frac{\lambda_0}{4}$

space of an electromagnetic radiation to be received or transmitted by the steerable antenna, and ϵ_r is a relative permittivity of a structure of dielectric material including the antenna elements. This preferred embodiment represents a good trade-off between directivity and size of the antenna. Preferably, $\epsilon_r = 1$. Preferably, said minimal distance between one passive antenna element of first antenna group and one antenna

$X \times 1$

element of second antenna group is equal to $\frac{\lambda_0}{2}$.

[0022] Preferably, the steerable antenna comprises a total number of antenna elements comprised between 10 and 32. According to this preferred embodiment, the cost and size of the antenna can be further reduced. This preferred embodiment represents also a good trade-off between good radiation properties and cost/size. More preferably, the antenna of the invention comprises a total number of antenna elements comprised between 12 and 24 (and still more preferably between 16 and 20).

[0023] Preferably, said first and second antenna groups comprise a same number of antenna elements, $M=N$. This preferred embodiment allows reducing modifications of the radiation diagram when it rotates. In other words, the global shape of the radiation pattern then does not change significantly when direction of maximum of radiation rotates. It is even possible, with this preferred embodiment, to cancel any modification of the radiation pattern as it rotates.

[0024] Preferably, said closed outer contour line is a circle.

Then, it is possible to further decrease any modification of the radiation diagram as it rotates, thanks to the circular symmetry.

[0025] Preferably, said M antenna elements of first antenna group are arranged along a closed inner contour line. Preferably, this closed inner contour line is a circle. Then, it is possible to further decrease any modification of the radiation diagram as it rotates, thanks to the circular symmetry.

[0026] Preferably, said closed inner contour line and said closed outer contour line are concentric circles. Then, it is possible to further decrease any modification of the radiation diagram as it rotates, thanks to the circular symmetry.

[0027] Preferably, the steerable antenna only comprises antenna elements along said inner and outer contour lines.

[0028] Preferably, said first antenna group comprises between three and twelve antenna elements, $3 < M < 12$. With a minimum of three antenna elements for first antenna group, one can have a steerable antenna with good properties, and the possibility to have more than two directions of main radiation. Moreover, the use of minimum three elements for first antenna group allows having a collective effect of antenna elements of first antenna groups. The first antenna group could comprise four, five, six, seven, eight, nine, ten, or more antenna elements.

[0029] Preferably, said second antenna group comprises between three and twelve antenna elements, $3 < N < 12$. With a minimum of three antenna elements for second antenna group, one can have an antenna with good properties, and the

(21) and surrounding the M antenna elements (5) of said first antenna group;

- switching means (100) coupled to the N antenna elements (5) of the second antenna group;

- a controller (110) programmed for controlling said switching means (100); said method comprising the step of sequentially switching to be active and at different times N antenna elements (5) of the second antenna group, $1 < N < N-1$, while switching to be passive and at same different times N-Na other antenna elements (5) of the second antenna group.

possibility to have more than two directions of main radiation. The second antenna group could comprise four, five, six, seven, eight, nine, ten, or more antenna elements.

[0030] Preferably, said first antenna group comprises six antenna elements that are passive permanently, and said second antenna group comprises six antenna elements, $N=6$.

[0031] Preferably, said switching means are electrically connected to the six antenna elements of the second antenna group for sequentially switching to be active at different times one different antenna subgroup comprising three antenna elements of the second antenna group while switching to be passive at same different times the other three antenna elements of said second antenna group. This preferred embodiment is a good trade-off between good properties of the antenna (in particular, its directivity and the possibility of having a radiation pattern that undergoes few changes when it rotates) and its cost of fabrication.

[0032] Preferably, said first antenna group comprises eight antenna elements, $M=8$; and said second antenna group comprises eight antenna elements, $N=8$. By using eight antenna elements for first and/or second antenna group, a smooth rotation of the radiating diagram can be obtained.

[0033] Preferably, at least one antenna element of the steerable antenna is an electrical monopole. More preferably, all the antenna elements of the steerable antenna are electrical monopoles. Cost of the antenna can be further reduced with this preferred embodiment as it is easy and cheap to design and fabricate an electrical monopole. A compact antenna can also be obtained with this preferred embodiment as an electrical monopole can be made small. [0034] Preferably, the steerable antenna comprises an additional passively terminated antenna elements that is located near (ie preferably within about 0.2 working wavelength) the center of inner and outer contour lines. This allows further increasing the directivity of the steerable antenna.

[0035] According to a second aspect, the invention relates to a method for controlling a steerable antenna comprising:

- a first antenna group comprising M antenna elements, $M > 1$;
- a second antenna group comprising N antenna elements, $N > 1$, said N antenna elements being disposed along a closed outer contour line and surrounding the M antenna elements of said first antenna group;
- switching means coupled to the N antenna elements of the second antenna group;
- a controller programmed for controlling said switching means.

Said method comprises the step of sequentially switching to be active and at different times N_a antenna elements of the second antenna group, $1 < N_a < N-1$, while switching to be passive and at same different times $N-N_a$ other antenna elements of the second antenna group.

[0036] Preferably, the method of the invention further comprises the step of connecting L antenna elements of first antenna group, $1 < L < M$, to different termination loads of L inner termination groups as main radiation lobe of said steerable antenna rotates.

[0037] Preferably, the method of the invention further comprises the step of connecting K antenna elements of first antenna group, $1 < K < N$, to different termination loads of K inner termination switches as main radiation lobe of said steerable antenna rotates.

Short description of the drawings

[0038] These and further aspects of the invention will be explained in greater detail by way of example and with reference to the accompanying drawings in which:

Fig.1 shows a top view of a preferred embodiment of a steerable antenna according to the invention at a time t_1 ; Fig.2 shows a top view of same preferred embodiment of a steerable antenna according to the invention at a time $t_2 > t_1$;

Fig.3 shows a top view of another preferred embodiment of a steerable antenna according to the invention;

Fig.4 shows a top view of another preferred embodiment of a steerable antenna according to the invention at a time t_1 ;

Fig.5 shows same preferred embodiment of a steerable antenna according to the invention at a time $t_2 > t_1$;

Fig.6 shows a top view of another preferred embodiment of a steerable antenna according to the invention ;

Fig.7 shows a top view of another preferred embodiment of a steerable antenna according to the invention at a time t_1 ;

Fig.8 shows a top view of same preferred embodiment of a steerable antenna according to the invention at a time $t_2 > t_1$;

Fig.9 shows a comparison between simulated radiation patterns (radial scale in dB) obtained with an ESPAR antenna and with an antenna according to the invention;

Fig.10 shows a comparison between simulated and measured radiation patterns (radial scale in dB) obtained with an antenna according to the invention;

Fig.11 shows measured radiation patterns (radial scale in dB) obtained with an antenna according to the invention;

Fig.12 shows a comparison between simulated radiation patterns (radial scale in dB) obtained with an ESPAR antenna and with an antenna according to the invention;

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Fig.13 shows a top view at a given time of a preferred embodiment of the steerable antenna;

Fig.14 shows a calculated radiation pattern for the preferred embodiment of previous figure, at same given time;

Fig.15 shows a top view at a given time of a preferred embodiment of the steerable antenna;

Fig.16 shows a calculated radiation pattern for the preferred embodiment of previous figure, at same given time. The drawings of the figures are neither drawn to scale nor proportioned. Generally, identical components are denoted by the same reference numerals in the figures.

Detailed description of embodiments of the invention

[0039] Figures 1 and 2 show a top view of a preferred embodiment of a steerable antenna 1 according to the invention at two different times t_1 and t_2 , with $t_2 > t_1$. The term 'steerable' is known by the one skilled in the art. A steerable antenna is a directional antenna whose main radiation lobe can be readily shifted in direction. The main radiation lobe of an antenna is the radiation lobe containing the maximum power in a polar radiation diagram. A directional antenna or beam antenna is an antenna which radiates more power in one or more directions with respect to the others. Hence, a directional antenna does not present isotropic properties and allows obtaining increased transmitting and receiving performances in some directions. An example of directional antenna is a YAGI antenna.

[0040] The steerable antenna 1 of the invention comprises a first antenna group comprising M antenna elements 5, $M > 1$. In the preferred embodiment shown in figures 1 and 2, the first antenna group comprises two antenna elements 5 that are assumed to be always passive ($M=2$); therefore, these antenna elements 5 are denoted by 5p. The steerable antenna 1 of the invention also comprises a second antenna group comprising N antenna elements 5 with $N > 1$. In the preferred embodiment shown in figures 1 and 2, the second antenna group comprises four antenna elements 5, so $N = 4$. The antenna elements 5 of the second antenna group are disposed or arranged along a closed outer contour line 21 and they surround the antenna elements 5p of the first antenna group. As shown in figures 1 and 2, the antenna elements 5 of the second antenna group are preferably substantially uniformly disposed along the closed outer contour line 21. The antenna elements 5 are preferably supported by (or mechanically coupled to) a structure of dielectric material that is not shown in figures 1 and 2. More preferably, such a structure of dielectric material is substantially planar. Then, this structure is preferably printed on a dielectric material.

[0041] An antenna element 5 is an element that can support electric currents (or equivalent electric / magnetic currents) which contribute to radiation. According to the present invention, an antenna element 5 can be an antenna array comprising several elements. Therefore, an antenna element 5 could be a small entity comprising different elements. Preferably, the antenna elements 5 are terminated by a given port, for instance by a generator (sometimes named transmitter), a receiver, an inductive load, or a capacitive load. Other termination ports are possible. The terms equivalent electric current and equivalent magnetic currents are known by the one skilled in the art. According to the surface equivalence principle, fields radiated outside a volume containing all the sources of these fields can be viewed as radiated by equivalent electric and magnetic currents on the surface bounding the volume (see for instance surface equivalence principle, Harrington, 1961, Section 3.5; Harrington, R. F., Time-harmonic Electromagnetic Fields, McGraw-Hill, London, 1961).

[0042] The antenna elements 5 of the steerable antenna 1 can be made of different types of materials. Preferably, the antenna elements 5 are metallic. An antenna element 5 can have different electromagnetic functions. Examples of antenna elements 5 that can be used for the invention are: electrical monopole, electrical dipole, magnetic dipole. The antenna elements 5 of the steerable antenna 1 of the invention can be different or identical.

[0043] An antenna element 5 can be passive or active. The term 'passive' is known by the one skilled in the art, and is also sometimes referred to as parasitic. An example of antenna that uses passive antenna elements is the YAGI antenna. A passive antenna element 5p is an antenna element 5 that is not connected to a receiver or a generator. Receiver and generator are known by the one skilled in the art. A receiver is an electronic device that receives or absorbs electromagnetic waves traveling along a line and that converts those waves in usable form, into a varying voltage for instance. A generator is an electronic device that generates an alternating current for instance, said alternating current exciting the active antenna elements 5a that thereafter radiate electromagnetic waves. Passive antenna elements 5p are preferably electrically connected to ground, or left open, or terminated into a capacitive or inductive load. The load of passive antenna elements 5p preferably involves a small resistive part. An active antenna element 5a is an antenna element 5 that is connected to a receiver or a generator, generally through a transmission line (or feed line). An active antenna element 5a is capable of transmitting or receiving electromagnetic waves (or radio signals): they are therefore sometimes named as driven antenna elements.

[0044] The purpose of passive antenna elements 5p is generally to modify the radiation pattern of the electromagnetic waves emitted by the active antenna elements 5a, directing them in one direction, and increasing the directivity of an antenna. A passive antenna element 5p does this by acting as a passive resonator, on which electric currents (or equivalent electric and magnetic currents) are excited in the presence of the active antenna elements 5a, with those excited currents re-radiating such fields with a different phase, as compared to the field generated by the active antenna elements 5a. The waves from the different antenna elements 5 interfere, strengthening the radiation of the antenna in the desired direction, and cancelling out the waves in undesired directions. Any scattering element can be used as passive antenna element 5p.

[0045] The steerable antenna 1 of the invention comprises switching means 100 and a controller 110. The switching means 100 are coupled to the N antenna elements 5 of the second antenna group ($N > 1$). Preferably, the switching means are electrically connected to the antenna elements 5 of the second antenna group. Still more preferably, they are

connected to the antenna elements 5 of the second antenna group through transmission lines 70. The controller 1 10 allows controlling the switching means 100 and is programmed such that, in use, N_a antenna elements 5 are switched at different times to be active, while $N - N_a$ other antenna elements 5 of the second antenna group are switched to be passive at same different times. N_a can take any integer value between 1 and $N - 1$. In the preferred embodiment shown in figures 1 and 2,

$N_a = 2$ and $N - N_a = 2$. Hence, the switching means 100 sequentially connect at different times at least one antenna element 5 of the second antenna group to a receiver or a generator 60 of microwave signals, while disconnecting at the same time the other antenna element(s) of the second antenna group from said receiver or a generator 60 of microwave signals. The preferred steerable antenna 1 shown in figures 1 and 2 is a transmitting (or emitting) antenna comprising a generator 60. In figures 1 and 2, a transmission line 70 drawn with solid line segments stands for an 'active' transmission line 70. This means that the antenna element 5 connected at one end of this transmission line 70 is active. Hence, the switching means 100 connect such an 'active' transmission line 70 and the antenna element 5 connected at one end of this 'active' transmission line 70 to the generator 60. A transmission line 70 drawn with dashed line segments stands for a 'passive' transmission line 70 which means that the antenna element 5 connected at one end of the transmission line 70 is passive. Hence, the switching means 100 disconnect such a 'passive' transmission line 70 and the antenna element 5 connected at one end of this 'passive' transmission line 70 from the generator 60. In the preferred embodiment shown in figures 1 and 2, N_a is equal to 2 for both t_1 and t_2 . Nevertheless, N_a could change between the different time intervals. For instance, N_a could be equal to one for a time t_1 , to three for a time $t_2 > t_1$, and to two for a time $t_3 > t_2$. In a preferred embodiment, for $N_a > 1$, the lengths of transmission line can be adjusted in order to produce appropriate phase shifts between (equivalent) current on the different active antenna elements 5a and, in turn, to increase the directivity of the whole antenna.

[0046] Different types of switching means 100 can be used as it is known by the one skilled in the art. Examples of switching means are: integrated switches, diodes. Other types of switching means could be used. The controller 1 10 is preferably a microcontroller.

[0047] The steerable antenna 1 further comprises L inner termination groups 215, $1 < L < M$, each of them comprising a plurality of different termination loads 220 (not shown in figures 1 and 2). The switching means 100 comprise L inner termination switches 205 (not shown in figures 1 and 2), each of them being connected in between one antenna element 5 of first antenna group and the different termination loads 220 of one different of said L inner termination groups 205. The controller 1 10 is programmed for controlling the L inner termination switches 205 for connecting and disconnecting each of L antenna elements of first antenna group to and from the termination loads 220 of one different inner termination group 215. These features will be explained in greater details with figures 6 and 7.

[0048] By sequentially activating all the antenna elements 5 of the second antenna group, a radiation pattern performing a 360° rotation can be obtained. The black arrow shown in figures 1 and 2 indicates the direction of the main radiation lobe. We can see that thanks to the successive activation of different antenna elements 5 of the second antenna group, the direction of the main radiation lobe has rotated counterclockwise. The same reasoning holds for a receiving antenna as it is known by the one skilled in the art and following the principle of reciprocity.

[0049] Preferably, two or three antenna elements 5 of the second antenna group are switched to be active at the same time: $N_a > 1$. This allows having a higher directivity or gain. In the preferred embodiment shown in figures 1 and 2, two antenna elements 5 of the second antenna group are switched to be active at the same time ($N_a = 2$). The term 'gain' is known by the one skilled in the art. The gain, G , is given by the following equation:

$$G = E \cdot D \quad (\text{Eq. 1})$$

where E is the efficiency and D the directivity.

[0050] It is not necessary that the controller 1 10 is programmed such that the switching means 100 sequentially switch all the antenna elements 5 of the second antenna group to be active at different times. If it is not wanted that the radiation pattern performs a 360° rotation, the controller 1 10 can indeed be programmed such that the switching means 100 switch only some of the antenna elements 5 of the second antenna group to be active during a period. A period is the duration between two different times at which a same antenna element 5 has been switched from a passive state to an active state. For instance, if a 270° rotation of the radiation pattern is wanted with the preferred embodiment shown in figures 1 and 2, only three antenna elements 5 of the second antenna group need to be switched sequentially to be active. Moreover, it is possible to have other antenna elements 5 disposed along the closed outer contour line 21 and that are not coupled to the switching means 100. The second antenna group only comprises N antenna elements 5 that are coupled to the switching means 100.

[0051] Figure 3 shows a top view of another preferred embodiment of the steerable antenna 1 according to the invention. In this preferred embodiment, the first antenna group comprises three antenna elements 5, and the second antenna group comprises four antenna elements 5 ($N = 4$). The antenna elements 5 of first (respectively second) antenna group are arranged along a closed inner (respectively outer) contour line 1 1 (respectively 21). In figure 3, the switching means 100 and the controller 1 10 are not depicted for clarity reasons.

[0052] Figures 4 and 5 show two top views of another preferred embodiment of the steerable antenna 1 of the invention at two different times, t_1 and t_2 , when the steerable antenna 1 is in operation ($t_2 > t_1$). For clarity reasons, the switching means 100 and the controller 1 10 are not depicted in these two figures. In this preferred embodiment, the first antenna group comprises six antenna elements 5 ($M = 6$), and the second antenna group also comprises six antenna elements 5 ($N = 6$). The antenna elements 5 of first (respectively second) antenna group are arranged along a closed inner (respectively outer) contour line 1 1 (respectively 21). Preferably and as shown in figures 4 and 5, all the antenna

elements 5 of the first antenna group are always passive (or passive permanently). These antenna elements are therefore denoted by 5p in figures 4 and 5. In the preferred embodiment shown in figure 4, three antenna elements, 5a, of the second antenna group are active at a time t1 while the other three antenna elements, 5p, are passive at the same time t1 ($N_a = 3$ and $N - N_a = 3$). Hence, at time t1, the switching means 100 have switched three antenna elements of the second antenna group and denoted by 5a in figure 4 to be active. The steerable antenna 1 therefore presents by symmetry a main transmitting or receiving direction parallel to the horizontal black arrow shown at figure 4. At a subsequent time t2 (figure 5), the switching means 100 have switched three antenna elements denoted by 5a in figure 5 to be active, while switching the other antenna elements 5p of figure 5 to be passive. So, for both times t1 and t2, the second antenna group comprises three active antenna elements 5a in this example ($N_a = 3$). The main transmitting or receiving direction (represented by a black arrow) of the steerable antenna 1 has rotated between t1 and t2 as the set of active antenna elements 5a has changed between t1 and t2. In the example shown in these two figures, this main transmitting or receiving direction has rotated counterclockwise between t1 and t2. Hence, the roles of some antenna elements 5 of the second antenna group have changed between active and passive, and conversely, for inducing the radiating diagram of the steerable antenna 1 to rotate.

[0053] In a preferred embodiment, the switching means 100 are coupled to some or all the antenna elements 5 of the first antenna group.

[0054] Preferably, signals from the generator 60 (also named transmitter) or toward the receiver are obtained or combined through the use of a splitter circuit. In this preferred embodiment, the generator 60 is thus not directly connected to the switching means 100 as shown in figures 1 and 2, but rather through such a splitter circuit.

[0055] Preferably, the switching means 100 switches several antenna elements 5 of the second antenna group to be active at a same time (as for the example shown in figures 1, 2, 4 and 5): $N_a > 1$. Then, it is preferred that the distance between the two active antenna elements 5a that are the farthest from each other is comprised between the radius and the largest diameter of the closed outer contour line 21.

[0056] Preferably, the antenna elements are separated by a minimum

$X \geq \frac{\lambda_0}{2}$

distance of $\frac{\lambda_0}{2}$, where λ_0 is the wavelength in free space of the

electromagnetic radiation to be received or transmitted by the steerable antenna 1, and ϵ_r is the relative permittivity of the structure of dielectric material supporting the antenna elements 5.

[0057] Preferably, the length (or largest dimension) of the antenna

$X \geq \frac{\lambda_0}{2}$

elements 5 is larger than $\frac{\lambda_0}{2}$, where λ_0 is the wavelength in free space of the electromagnetic radiation to be received or transmitted by the steerable antenna 1, and ϵ_r is the relative permittivity of the structure of dielectric material supporting the antenna elements 5. [0058] When at least two antenna elements 5 of the second antenna group are active at same times (examples of figures 1, 2, 4 and 5: $N_a > 1$), a phase shifting technique between the antenna elements 5 active at same times is preferably used for obtaining a still higher directivity. Phase shifting technique among signals radiated by or received from different active antenna elements 5a is achieved either through the use of transmission lines of different lengths or through the use of phase shifting circuits. By using a phase shifting technique, the electromagnetic waves from the different active antenna elements 5a interfere, strengthening the antenna's radiation in the desired direction, and cancelling out the waves in undesired directions.

[0059] As mentioned previously:

- the steerable antenna 1 comprises at least one inner termination group 215 (L inner termination groups 215, with $L \in [1, M]$), each of said at least one inner termination group 215 comprising at least two (or a plurality of) different termination loads 220;

- the switching means 100 comprise at least one (L with $L \in [1, M]$) inner termination switch 205, each of the at least one inner termination switch 205 coupled to one of the at least one antenna element 5 of the first antenna group and coupled to the at least two different termination loads 220 of one different of the at least one inner termination group 215; and

- the controller 110 is also programmed for controlling the at least one inner termination switch 205 for connecting and disconnecting at least one of the at least one antenna element 5 of the first antenna group to and from the termination loads 220 of one different inner termination group 215.

[0060] Preferably:

- the steerable antenna 1 of the invention further comprises K outer termination groups 210, $K \in [1, N]$, each outer termination group 210 comprising at least two different termination loads 220;

- the switching means 100 comprise K outer termination switches 200 each coupled to one different antenna element 5 of the N antenna elements 5 of the second antenna group and each coupled to the at least two different termination loads 220 of one different outer termination group 210; and
- the controller 110 is also programmed for controlling the K outer

termination switches 200 for connecting and disconnecting each of K antenna elements 5 of the second antenna group to and from the termination loads 220 of one different outer termination group 210.

[0061] Examples of inner 205 and outer 200 termination switches are: integrated switches and switching diodes. Other types of switching devices could be used. An example of the combination 'switch + termination load 220' is a varicap diode that is known by the one skilled in the art.

[0062] Figure 6 shows at a given time a top view of such a preferred embodiment of the steerable antenna 1 where $L=6$ and $K=6$ (six inner 215 and six outer 210 termination groups). In the preferred embodiment of figure 6, the switching means comprise six outer termination switches 200, and six inner termination switches 205. The preferred steerable antenna 1 shown in figure 6 has a first antenna group comprising six passive antenna elements 5p, and has a second antenna group comprising six other antenna elements 5 ($N=6$). At the time corresponding to the configuration shown in figure 6, three antenna elements 5 of the second antenna group are active, whereas the other three antenna elements 5 of the second antenna group are passive. The black arrow shows the direction of main radiation. Each outer termination group 210 comprises two different termination loads 220 (for clarity reasons, only some 220 reference signs are shown in figure 6). Each inner termination group 215 comprises two different termination loads 220 (for clarity reasons, only some 220 reference signs are shown in figure 6). The termination loads 220 are preferably open transmission lines of different lengths. Depending on the length of these open transmission lines, they behave as different types of impedances.

For instance, these open transmission lines can behave as an inductance, a capacitor, or as an open circuit (impedance tending to infinity). Other ways of realizing the termination loads could be exploited. For clarity reasons, the controller 1 10 is not shown in figure 6. The lengths of open transmission lines determine the impedance provided as an antenna load. Let us define by λ_g the wavelength of the waves propagating in the transmission line. Approximately, for open-ended lines, the load at the antenna level will be capacitive if the line length is less than $\lambda_g/4$ and inductive if it is between $\lambda_g/4$ and $\lambda_g/2$; these correspond to purely imaginary impedances. Some real (i.e. resistive) part of the load may appear because of the losses in the transmission line. The switches also modify a little the real and imaginary parts of the impedance. The dependence of the load on line length is described by classical transmission-line theory.

[0063] Figures 7 and 8 show two top views of another preferred embodiment of the steerable antenna 1 at two successive times t_1 and t_2 , with $t_2 > t_1$. In this preferred embodiment, the steerable antenna 1 comprises six outer termination groups 210 each comprising two different termination loads: 220a and 220b. For clarity reasons, these reference signs (220a and 220b) are not shown for all the outer termination groups 210. In this preferred embodiment, the steerable antenna 1 also comprises six inner termination groups 215. Each inner termination group 215 comprises three different termination loads: 220c, 220d, and 220e. For clarity reasons, these reference signs (220c, 220d, and 220e) are not shown for all the inner termination groups 215 and the reference sign 215 is not indicated for all the different inner termination groups. For clarity reasons, the controller 1 10 is neither shown in figures 7 and 8. The preferred steerable antenna 1 shown in figures 7 and 8 has a first antenna group comprising six passive antenna elements 5p, and has a second antenna group comprising six other antenna elements 5 ($N=6$). However, this preferred embodiment of the steerable antenna 1 could have a larger or a smaller number of antenna elements 5.

[0064] At t_1 , the time corresponding to the configuration shown in figure 7, three antenna elements 5a of the second antenna group are active, and the other three antenna elements 5p are passive ($N_a=3$ and $N-N_a=3$). The controller then controls the outer termination switches 200 coupled to the three active antenna elements 5a for disconnecting them from any termination load 220. The termination loads 220 that are disconnected from any antenna element 5 are represented by dashed line segments in figures 7 and 8. The termination loads 220 that are connected to an antenna element 5 are represented by solid line segments in figures 7 and 8. The passive antenna elements 5p of the second antenna group are each connected to a termination load 220 so as to obtain load symmetry with respect to the main direction of radiation. As a reminder, this main direction of radiation is depicted by a black arrow. Therefore, two passive antenna elements 5p of the second antenna group are connected to a same second termination load 220b, whereas the other passive antenna elements 5p of the second antenna group that is located in between these two passive antenna elements 5p is connected to a first termination load 220a. The passive antenna elements 5p of the first antenna group are connected to different termination loads 220 also in order to obtain load symmetry with respect to the main direction of radiation. Therefore, the most left-side passive antenna element 5p is connected to a fourth termination load 220d. The two passive antenna elements 5p adjacent to said most left-side passive antenna element 5p are also connected to said fourth termination load 220d. The most right-side passive antenna element 5p of the first antenna group is connected to a fifth termination load 220e, whereas the two passive antenna elements 5p adjacent to said most right-side passive antenna element 5p are connected to a third termination load 220c.

[0065] At t_2 , the time corresponding to the configuration shown in figure 8, the main direction of radiation has rotated clockwise. The active and passive roles of the antenna elements 5 of the second antenna group have changed. The controller has also changed the states of the outer 200 and inner 205 termination switches in order to keep load symmetry with respect to the main direction of radiation: hence, the states of the outer 200 and inner 205 termination switches have also rotated clockwise. This specific loading of the different antenna elements 5 of the steerable antenna 1 that impose load symmetry with respect to the main direction of radiation (or reception) allows having a still higher directivity. In figure 8, three active antenna elements 5a of the second antenna group are disconnected from any termination load 220. Two passive antenna elements 5p of the second antenna group are connected to a same second termination load 220b. The passive antenna element 5p that is positioned in between these two passive antenna elements 5p is connected to a first termination load 220a. Three passive antenna elements 5p of the first antenna group are connected to a same fourth termination load 220d. Two passive antenna elements 5p of the first antenna group are connected to a same third termination load 220c, and the passive antenna element 5p that is positioned in between these two passive antenna elements 5p is connected to a fifth termination load 220e.

[0066] For all the possible embodiments of the steerable antenna 1, notably for the preferred embodiments shown in figures 1-8, the antenna elements 5 can be of various shapes, of various sizes, and with different electromagnetic functions. Examples of shapes for the antenna elements 5 are: a loop, a rod, a hollow cylinder, a U-shape. Other shapes are possible. All the antenna elements 5 can have a same shape or can have different shapes. All the antenna elements 5 can have a same size or the antenna elements 5 can have different sizes. The antenna elements 5 can be made of different types of materials. Preferably, the antenna elements 5 are metallic. More preferably, they are made of copper. The antenna elements 5 can be for instance: electrical monopoles, electrical dipoles, magnetic dipoles. The antenna elements 5 can be different or identical. So, for instance, it is possible to have an antenna element 5 that is an electrical monopole and another antenna element 5 that is an electrical dipole. Other combinations are possible.

[0067] Preferably, some or all the antenna elements 5 comprise a cylindrical element that is electrically insulated from a grounding plate. Preferably, these cylindrical elements have a length of $0.15 \lambda_g - 0.3 \lambda_g$ where $\lambda_g = \lambda_0 / \sqrt{\epsilon_r}$ where λ_0 is the working free space wavelength of the radio signal, and ϵ_r is a relative permittivity of a medium containing the antenna elements 5. Preferably, outer conductors of coaxial cables (or microstrips or striplines) are connected to a grounding plate whereas the central conductors of these coaxial cables are connected to one end of the cylindrical elements.

[0068] In all the embodiments described above, it is possible to have other antenna elements 5 surrounding the second antenna group.

[0069] In the above description, it should be understood that the features of the steerable antenna 1 apply whether it is used for transmitting or receiving. For a passive antenna element 5p, the properties are the same for both the receiving and transmitting modes. Therefore, no confusion should result from a description that is made in terms of one or the other mode of operation and it is well understood by those skilled in the art that the invention is not limited to one or the other mode.

[0070] Preferably, the steerable antenna 1 of the invention is used in the following frequency range, 433 MHz - 24 GHz, and more preferably, in the range 800 MHz - 12 GHz.

[0071] Results are now presented. Figure 9 shows a comparison between two simulated radiation diagrams in an azimuthally plane, between 0° and 360° (radial scale in dB). These two radiation diagrams are normalized to 15 dB. Black solid curve is a radiation diagram of a steerable antenna 1 according to the invention and according to the preferred embodiment of figures 4 to 5: each of first and second antenna groups of the steerable antenna 1 comprises six antenna elements 5 (so, $N=6$), the closed outer contour line 21 is a circle, and the antenna elements 5 of the first antenna group are arranged along a closed inner contour line 11 that is a circle concentric to the closed outer contour line 21. Three antenna elements 5 are active at a same time ($N_a=3$), the other ones being terminated with optimized values of reactance. Dashed curve is radiation diagram of an optimized ESPAR antenna comprising one central active antenna element surrounded by six passive antenna elements. From figure 9, we can see that the directivity increases with the steerable antenna 1 according to the invention. In particular, the back lobe of the radiation pattern of the ESPAR antenna is not present in the radiation diagram of the steerable antenna 1 according to the invention. In fact, simulated directivity values as high as 12 dBi can be obtained with the steerable antenna 1 of the invention and according to the above-mentioned preferred embodiment (the dBi unit is known by the one skilled in the art). This value is much larger than the directivity of 7 dBi that is obtained from simulations with an ESPAR antenna as described few lines above (one active central antenna element surrounded by six passive antenna elements). Hence, the steerable antenna 1 according to the invention is approximately 5 dBi more directive than the ESPAR antenna.

[0072] A measurement executed on an integrated version of the antenna according to the invention has shown a directivity close to 11 dBi. [0073] Figure 10 shows two radiation patterns in an azimuthal plane, between 0° and 360° for a steerable antenna 1 according to the invention and for the same preferred embodiment as the one in relation with the results shown in figure 9. Dashed curve represents a measured radiation pattern in an anechoic chamber, whereas solid curve is a simulated radiation pattern. The patterns are normalized to 25 dB. This figure shows a relatively good correspondence between simulation and measurement. A small difference in the measured sidelobes can be attributed to the fact that the fabricated prototype comes with losses in the switches and transmission lines in the PCB boards used to get the switched reactances.

[0074] Figure 11 shows, at six different times (see the six different positions in the legend of figure 11), measured radiation patterns obtained with the preferred embodiment of the steerable antenna 1 that has been described in relation to figure 9. From this figure, we clearly see the rotation of the radiation pattern between the six different times.

[0075] The directivity of the steerable antenna 1 according to the invention is higher than that of an ESPAR antenna even if only one antenna element 5 of the second antenna group is active at a same time ($N_a=1$). When each of first and second antenna groups of the steerable antenna 1 according to the invention comprises six antenna elements with $N_a=1$, simulated directivity is around 7.3 dBi for the steerable antenna 1 of the invention, while the simulated directivity is around 7 dBi for an ESPAR antenna. Figure 12 shows different simulated radiation patterns (310, 320, and 330) in an azimuthal plane between 0° and 360° . Pattern 310 relates to the radiation pattern of an ESPAR antenna. Patterns 320 and 330 relate to radiation patterns of a steerable antenna 1 according to the invention, when each of first and second antenna groups comprises six antenna elements 5, when $N_a=1$, and when the antenna elements 5 of the first antenna group are arranged along a circle that is concentric to the closed outer contour line that is also a circle. Pattern 320 has been simulated with a CST (Computer Simulation Technology, www.cst.com) approach, whereas pattern 330 has been simulated with a method of moment that is known by the one skilled in the art. From this figure, we see that the steerable antenna 1 is competitive compared to an ESPAR antenna even when $N_a=1$, in particular because back lobe 300 is suppressed.

[0076] Figure 13 shows a top view of a steerable antenna 1 according to a preferred embodiment of the invention. For this steerable antenna 1, $M=N=L=K=6$, and $N_a=3$. This figure also relates to a configuration of the steerable antenna 1 when main radiation lobe (or main radiation) is directed along the black arrow of figure 13. All antenna elements of first antenna group are passive permanently. The points represent the antenna elements. The complex values of the termination loads of the different antenna elements are written on figure 13 in ohms for a working frequency of 2.45 GHz, and assuming that a 50 Ohm generator is used for feeding the steerable antenna 1 (as known by the one skilled in the art, $j = \sqrt{-1}$). Radius of inner contour line 11 is 0.3348 wavelengths, that of the outer contour line 21 is 0.6696 wavelengths. For the time corresponding to figure 13, three antenna elements of second antenna group with a termination load equal to 50-jO are active. All the other antenna elements are passive. From this figure, we can see that the termination loads of the different antenna elements are chosen so as to have symmetry in termination loads for the different antenna elements. For the geometry of figure 13, this corresponds to symmetry with respect to a horizontal line passing through the black arrow. The corresponding radiation pattern in the plane containing the array of antenna elements, as calculated with the Method of Moments, assuming that the antenna elements are monopoles protruding from a perfectly conducting plane is given in figure 14. This corresponds to a narrow main-beam and high sidelobes.

[0077] Figure 15 shows a top view of a steerable antenna 1 according to another preferred embodiment of the invention. For this steerable antenna 1, $M=N=L=K=8$, and $N_a=3$. This figure also relates to a configuration of the steerable antenna 1 when main radiation lobe (or main radiation) is directed along the black arrow of figure 15. All antenna elements of first antenna group are passive permanently. The points represent the antenna elements. The values of the termination loads of the different antenna elements are written on figure 15 in Ohms for a working frequency of 2.45 GHz, and assuming that a 50 Ohm generator is used for feeding the steerable antenna 1. Radius of inner contour line 11 is 0.49 wavelengths, that of the outer contour line 21 is 0.735 wavelengths. For the time corresponding to figure 15, three antenna elements of second antenna group with a termination load equal to 50-jO are active. All the other antenna elements are passive. From this figure, we can see that the termination loads of the different antenna elements are chosen so as to have symmetry in termination loads for the different antenna elements. For the geometry of figure 15, this corresponds to symmetry with respect to a horizontal line passing through the black arrow. The corresponding radiation pattern in the plane containing the array of antenna elements, as calculated with the Method of Moments and assuming that the antenna elements are monopoles protruding from a perfectly conducting plane, is given in figure 16.

[0078] The present invention has been described in terms of specific embodiments, which are illustrative of the invention and not to be construed as limiting. More generally, it will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and/or described hereinabove. Reference numerals in the claims do not limit their protective scope. Use of the verbs "to comprise", "to include", "to be composed of", or any other variant, as well as their respective conjugations, does not exclude the presence of elements other than those stated. Use of the article "a", "an" or "the" preceding an element does not exclude the presence of a plurality of such elements.

[0079] The invention may also be described as follows. Steerable antenna 1 comprising: a first antenna group comprising M antenna elements 5, $M > 1$, a second antenna group comprising N antenna elements 5, $N > 1$, said N antenna elements 5 being arranged along a closed outer contour line 21 and surrounding the M antenna elements 5 of the first antenna group. The steerable antenna 1 further comprises: switching means 100 coupled to the N antenna elements 5 of the second antenna group and a controller 110 programmed for controlling said switching means 100 for sequentially switching to be active and at different times successive antenna subgroups, each antenna subgroup comprising N_a antenna elements 5 of the second antenna group, $1 < N_a < N-1$, while switching at same different times $N-N_a$ other antenna element 5 of the second antenna group to be passive. The steerable antenna 1 also comprises L inner termination groups 215 and L inner termination switches 205, $1 < L < M$, allowing modifying the termination loads of the antenna elements 5 of first antenna group for improving the directivity of the steerable antenna 1. N is preferably equal to two, three, four, five, six, seven, eight, nine or ten. Preferably, the antenna elements of the first antenna group are connected through switching means to passive loads. Preferably, the antenna elements 5 of second antenna group are also connected to different passive loads at same different times through switching means.

CITATIONS DE BREVETS

Brevet cité	Date de dépôt	Date de publication	Déposant	Titre
US5294939 *	11 janv. 1993	15 mars 1994	Ball Corporation	Electronically reconfigurable antenna
US6317092 *	31 janv. 2000	13 nov. 2001	Focus Antennas, Inc.	Artificial dielectric lens antenna
US20050174298 *	8 avr. 2005	11 août 2005	Ipr Licensing, Inc.	Low cost multiple pattern antenna for use with multiple receiver systems

* Cité par l'examinateur

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Brevet citant	Date de dépôt	Date de publication	Déposant	Titre
WO2017043921A1 *	9 sept. 2016	16 mars 2017	엘지전자 주식회사	Method and device for performing communication with virtual terminal in wireless communication system

* Cité par l'examinateur

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Date	Code	Événement	Description
4 mars 2015	121	Ep: the epo has been informed by wipo that ep was designated in this application	Ref document number: 14736414 Country of ref document: EP Kind code of ref document: A1
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