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(54) **A radar decoy**

(57) A decoy comprises a parachute 1 which, in use, suspends a support column 2 from which hangs a thread 3 comprising multiple antenna array elements 4 and a power pack 6. The decoy has been released from containment in a separable casing 5a, 5b. The casing is launched into the air by a launcher (not shown). Each antenna array element comprises multiple conjugate antenna pairs in an array, each antenna pair connected by a transmission line, all transmission lines being of equal length and the antenna arranged equi-distantly about a centre of the array, and an amplifier associated with each transmission line.

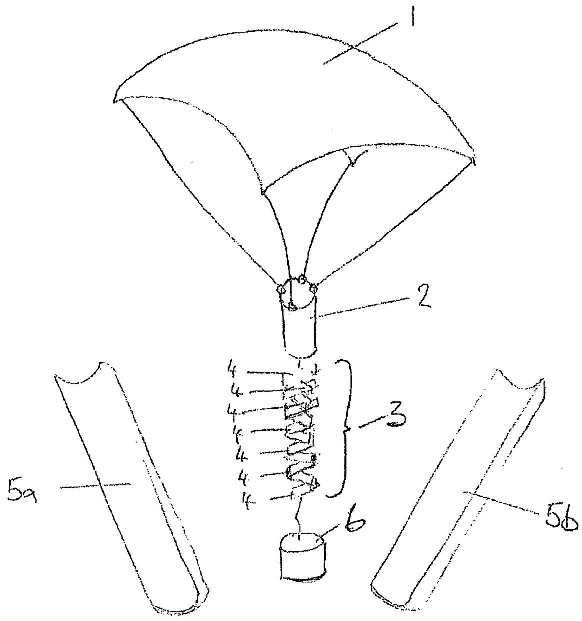

Fig 1

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Description

[0001] This invention relates to radar decoys in general but more particularly to radar decoys used in naval applications to distract or seduce oncoming radar guided threats from a target vessel and protect the vessel from damage. More specifically the invention relates to a retro-directive array operable in the IEEE X and Ku bands covering 8-18GHz and at higher radar frequencies including Ka band (27-40GHz) and W band (75-110GHz).

[0002] A radar decoy is applied as a countermeasure technique against radar guided threats. The aim is to distract or seduce the incoming threat from the primary target by presenting one or more secondary targets. The secondary target must present either an alternative target and hence prevent lock on to the primary target signature (distraction), or present a sufficiently large signature so as to be preferable to the primary target that has previously been acquired (seduction).

[0003] Chaff (or Window), typically small metallic ribbons or fibres, has been in use as a radar countermeasure since the origins of radar. The radar cross section (RCS), of each individual dipole element in the chaff may be much smaller than the target signature but, dispensed in large numbers over a large volume, chaff provides a large RCS for use as a distraction or seduction decoy. Chaff can be effective against older less sophisticated radars in X and Ku bands but may be discriminated from the real target because of its temporal or spatial characteristics. The RCS that can be achieved with chaff may also be too small depending on the RCS of the target, the frequency and polarisation of the threat radar and its resolution cell size. These factors are particularly important in vertical polarisation and at higher frequencies.

[0004] An alternative form of radar decoy is the trihedral corner reflector. This is a passive retro-reflective device that functions by reflection of the radar waves off mutually perpendicular planes and returning the incoming radiation back in the direction from which it came.

[0005] Amongst the advantages of the corner reflector are that it may be manufactured from lightweight materials and stowed efficiently in a small volume prior to deployment. The corner reflector is reliant on the use of radar reflective materials that are relatively cheap and easy to manufacture. The corner reflector decoy is less prone to discrimination from the real target by advanced radars.

[0006] However the need for fast erection and excellent dimensional accuracy and stability of the deployed reflector causes design difficulties and cost increases especially at higher radar frequencies. In addition the peak RCS is achieved only within a relatively narrow angular range at the optimal orientation.

[0007] Another class of retro-directive reflector is the phase conjugation device whereby the phase of an incoming wave front is reversed. Phase conjugation devices are of 3 different types - quasi-optic, the Van Atta array or the heterodyning array.

[0008] Quasi-optic devices are more relevant to higher frequency application (W band).

[0009] Heterodyning arrays are inherently narrow band devices with the need for a common local oscillator at twice the incident radar frequency.

[0010] For Van Atta arrays, first patented in 1959 (US2908002), the only frequency dependence is the antenna element and, using wide band elements, the whole array has instantaneous wide band width. In contrast to the corner reflector, the Van Atta array has a wider angular response.

[0011] The Van Atta patent is directed to passive devices. In order to obtain a large RCS sufficient for use as a decoy, passive Van Atta arrays would be too large to pack into a confined space for launching into the air. Even if this was possible, the subsequent deployment into a large flat array would be slow and difficult to achieve even with lightweight modern materials. The Van Atta array must therefore be designed as a more compact active array with amplification of the received signal and no need for any erection or deployment mechanisms.

[0012] In accordance with the present invention there is provided an active retro-directive decoy comprising a plurality of elements, each element comprising a Van Atta array of multiple antenna or antenna subarray pairs where each antenna pair is connected by a transmission line, all transmission lines being of equal length and the antenna arranged equidistant about the centre of the array. an amplifier associated with each transmission line connecting the receive antenna and transmit antenna in each pair; the plurality of elements aligned in string, a power source supplying power to the elements and a device for slowing descent of the string of elements through air.

[0013] In the preferred option a first antenna in each conjugate pair is configured to act as a receiver, the second antenna in each conjugate pair is configured to act as a transmitter and the amplifiers are unidirectional and configured to amplify the received signal for transmission.

[0014] In another option, each antenna in each conjugate pair is configured to act both as a receiver and a transmitter and the amplifiers are bi-directional.

[0015] In one preferred option, the plurality of elements consists of 8 arrays assembled as 4 pairs. Each pair is assembled back to back to face in opposite directions. Each of the 4 pairs is arrange on a central support structure one underneath the other and to point in 4 directions at 90° intervals. A DC power source supplies electrical power to the elements. The complete payload is deployed from a delivery vehicle such as a rocket or grenade and a device is used for slowing its descent through the air such as a parachute and a balloon. Devices for slowing the descent are not limited to a balloon or parachute and various other devices will no doubt occur to the skilled addressee.

[0016] The string of elements may also take any of a number of other configurations. In the preferred option, the elements are stacked along a common axis with an angular separation between various elements. The arrangement may be random or structured. For example, instead of each alternate element being aligned orthogonally to the intermediate elements, they may be grouped and alternative groups of elements may be aligned orthogonally to the intermediate groups. In another example, the elements may be spiralled with an angular spacing between adjacent elements of less than 90 degrees.

[0017] The power source is desirably a thermal battery power source that can provide sufficient voltage and current for the duration of the decoy use. Preferably the battery is one which can be safely disposed of after release of the decoy

[0018] Desirably, the decoy further includes a thermal management system. For example, the thermal management system might include Peltier cooling devices associated with the elements.

[0019] The elements may comprise arrays configured to scan in one or both of two different orthogonal planes. In one option, this can be achieved through individual elements being configured to scan in just one of the planes. In another option, individual elements comprise arrays configured for scanning in both of the two orthogonal planes (azimuth and elevation).

[0020] The elements can be conveniently manufactured as micro strip and/or stripline circuits into which the antennas and transmission lines are printed.

[0021] While the decoy will normally return the same amplified waveforms that it. receives, the electronics can be configured to delay, modulate or otherwise modify the returned waveform to enhance the decoy effect.

[0022] The decoys can conveniently be provided in a frangible casing and deployed by firing the frangible or separable casing from a launcher. On launch, the casing falls away exposing the decoy, a plurality of which might be enclosed in a single casing. Launchers of conventional design can be employed in the deployment of the decoys.

[0023] Some specific embodiments of the invention are now described in more detail with reference to the accompanying Figures In which:

Figure 1 shows an illustration of an embodiment of a decoy in accordance with the invention shortly after its deployment. Dimensions of component parts are not necessarily accurate.

Figure 2 shows a schematic of an antenna array for an element of a decoy in accordance with one embodiment of the invention

Figure 3 shows a schematic of an antenna array for an element of a decoy in accordance with a second embodiment of the invention

Figure 4 shows one practical embodiment of a manufactured element for use in a decoy in accordance with the present invention

Figure 5 shows a second practical embodiment of a manufactured element for use in a decoy in accordance with the present invention

Figure 6 shows a schematic of an array in one micro strip embodiment of an element for use in a decoy in accordance with the present invention.

Figure 7 shows an active retro directive antenna array which has been manufactured and successfully tested

[0024] As can be seen from Figure 1, a decoy comprises a parachute 1 from which hangs a support column 2 on which are mounted multiple antenna array elements 3 and a power pack 6. As shown in the Figure, the decoy has been released from containment in a separable casing 5a, 5b. The casing is launched into the air by a rocket powered round fired from a launcher (not shown).

[0025] Figure 2 shows schematic of an antenna array for an element of a decoy in accordance with one embodiment of the invention. As can be seen the array comprises multiple antennas arranged in conjugate pairs; 21a, 21a'; 21b, 21b', each pair being connected by a transmission line 22a, 22b. The transmission lines 22a, 22b are each of equal length. Integrated into each transmission line 22a, 22b is an amplifier 23a, 23b, which serves to amplify a received signal for retransmission. In this Figure, the amplifiers 23a and 23b are bidirectional and each antenna in each conjugate pair 21a, 21a'; 21b, 21b' is configured both to receive and re-transmit a wave front W of a radar signal.

[0026] Figure 3 shows a schematic of an antenna array for an element of a decoy in accordance with a second embodiment of the invention. As can be seen the array comprises multiple antennas arranged in conjugate pairs; 31a, 31a'; 31b, 31b'; 31c, 31c'; 31d, 31d', each pair being connected by a transmission line 32a, 32b, 32c, 32d. The transmission lines 32a, 32b, 32c, 32d are each of equal length. Integrated into each transmission line 32a, 32b, 32c, 32d is an amplifier 33a, 33b, 33c, 33d which serves to amplify a received signal for retransmission. In this embodiment a first antenna in each conjugate pair 31a, 31b, 31c, 31d is configured to receive and a second antenna in the pair 31a', 31b', 31c, 31d' is configured to re transmit the signal. The amplifiers 33a, 33b, 33c, 33d are unidirectional and arranged to amplify the signal received by the receiving antennas 31a, 31b, 31c, 31d before re- transmission by the transmitting antennas 31a', 31b', 31c', 31d'.

[0027] Figure 4 shows one practical embodiment of a manufactured element for use in a decoy in accordance with the present invention. The figure shows an exploded view of a multi-layered structure which in use would be tightly sandwiched together. The structure comprises a lower substrate layer 40, an upper substrate layer 41 and a copper ground plane layer 42 sandwiched between the upper substrate 41 and lower substrate layers 40. A patch antenna 41a is printed on the exposed surface of the upper substrate layer 41. A transmission line 40a is printed on the exposed surface of the lower substrate layer 40. A coupling aperture 42a is provided in the ground plane 40, directly beneath the antenna 41a.

[0028] The arrangement is advantageous in that it provides more space for routing of transmission lines 40a since they do not share the same surface area as the printed antennas 41a. Also, the transmission lines 40a are able to be fully decoupled from the antennas 41a and are coupled only intentionally via the coupling aperture 42a.

[0029] In use multiple elements can be stacked along a common axis (passing through the coupling apertures) to provide a desired antenna array. Figure 5 shows an alternative practical embodiment of a manufactured element for use in a decoy in accordance with the present invention. The element of Figure 5 has a single sided multi-layer micro strip structure. The element comprises a ground plane 50 on to one side of which is applied a base layer 51. An antenna substrate 52 sits on the base layer 51. A transmission line 51a is printed onto the base layer 51 and a dual ring antenna 52a is printed onto to the exposed surface of the antenna substrate 52.

[0030] Multiple elements may be stacked vertically to provide a wide bandwidth and arranged in lateral proximity to each other either individually or in subarrays to form a desired antenna array.

[0031] The proximity of the transmission lines 51a to the ground plane 50 helps to prevent radiating of the lines and results in lower losses than some other arrangements and reduced unintended coupling of elements.

[0032] In a development of this embodiment additional base layers can be provided in the layered structure permitting transmission lines on alternate layers to be crossed. This eases routing. The increased distance of the antennas from the ground plane reduces the quality factor Q of the antennas thereby improving bandwidth capability and impedance matching.

[0033] Figure 6 shows an array with azimuth scan using four sub arrays with fixed beam in elevation [Note, figure 6 needs rotating 90 degrees for this paragraph to be true]. Optimal array configurations for the contemplated applications of the decoy have been identified as very limited scan or fixed attitude in elevation with scan in azimuth. Figure 6 shows one practical embodiment which achieves this. The embodiment consists of linear sub arrays in the elevation plane arrayed connected in a 1 dimensional Van Atta configuration for azimuth scan. In the Figure, four element sub arrays are applied in elevation and the four sub arrays are arrayed in the azimuth plane to provide a scan capability in that plane.

[0034] Figure 7 shows an active retro directive antenna array which has been manufactured and successfully tested. The array uses separate receive and transmit arrays along with amplifiers to achieve the active operation. There are four arrays in total these are numbered respectively; 1-4; 5-8; 1'-4' and 5'-8'. Arrays 1-4 and 5-8 receive and 1'-4' and 5'-8' transmit. The corresponding receiving and transmitting pairs 1-4, 1'-4'; 5-8, 5'-8' are connected via micro-strip transmission lines 70 and amplifiers 70a. The arrays are arranged to achieve fixed broadside beam in elevation, using two elements to increase gain, and scan in azimuth. Power supplies to the amplifiers are rigged through the transmission lines. Vgs and Vds are gate and drain power to the amplifiers 70a very thin interconnect lines 71 which connect to the transmission lines 70 via inductors 71a which decouple the transmission lines from the power lines 72. The arrangement is very space efficient.

Claims

1. An active retro-directive decoy comprising a plurality of elements, each element comprising multiple conjugate antenna or antenna subarray pairs in an array, each antenna or subarray pair connected by a transmission line, all transmission lines being of equal length and the antenna arranged equi-distantly about a centre of the array, and an amplifier associated with each transmission line; the plurality of elements aligned in a string, a power source supplying power to the elements and a device for slowing descent of the decoy through the air.

2. An active retro-directive decoy as claimed in claim 1 wherein a first antenna in each conjugate pair is configured to act as a receiver and the second antenna in each conjugate pair is configured to act as a transmitter and the amplifiers are unidirectional and configured to amplify the received signal for transmission.

3. An active retro-directive decoy as claimed in claim 1 wherein each antenna in each conjugate pair is configured to act both as a receiver and a transmitter and the amplifiers are bi-directional.

4. An active retro-directive decoy as claimed in claim 1 wherein the amplifier electronics can be further configured to delay, modulate or otherwise modify the returned waveform to enhance the decoy effect.

5. An active retro-directive decoy as claimed in any preceding claim wherein the device for slowing the descent is a parachute.

6. An active retro-directive decoy as claimed in any of claims 1 to 3 wherein the device for slowing the descent is a baiioon.

7. An active retro-directive decoy as claimed in any preceding claim wherein the string of elements compris-

es elements stacked along a common axis with an angular separation between various elements.

8. An active retro-directive decoy as claimed in claim 7 wherein the stacked arrangement is random.

9. An active retro-directive decoy as claimed in claim 7 wherein the stacked arrangement is structured.

10. An active retro-directive decoy as claimed in claim 9 wherein each alternate element is aligned orthogonally to the intermediate elements.

11. An active retro-directive decoy as claimed in claim 9 wherein elements are grouped and alternative groups of elements are aligned orthogonally to the intermediate groups.

12. An active retro-directive decoy as claimed in claim 7 wherein the stacked arrangement comprises elements in a spiralled configuration with an angular spacing between adjacent elements of less than 90 degrees.

13. An active retro-directive decoy as claimed in any preceding claim wherein the power source is a dc power source.

14. An active retro-directive decoy as claimed in claim 13 wherein the dc power source is a thermal battery.

15. An active retro-directive decoy as claimed in any preceding claim wherein the decoy further includes a thermal management system.

16. An active retro-directive decoy as claimed in claim 15 wherein the thermal management system includes Peltier cooling devices associated with the elements.

17. An active retro-directive decoy as claimed in any preceding claim wherein the elements comprise arrays configured to scan in two different orthogonal planes (elevation and azimuth).

18. An active retro-directive decoy as claimed in claim 17 wherein individual elements are configured to scan in just one of the two planes.

19. An active retro-directive decoy as claimed in claim 17 wherein individual elements comprise arrays configured for scanning in both of the two orthogonal planes (azimuth and elevation).

20. An active retro-directive decoy as claimed in any preceding claim wherein the elements are manufactured as micro strip circuits into which the antennas and transmission lines are printed.

21. An active retro-directive decoy as claimed in any preceding claim wherein the decoy is provided in a frangible or separable casing and deployable by firing the frangible or separable casing from a launcher.

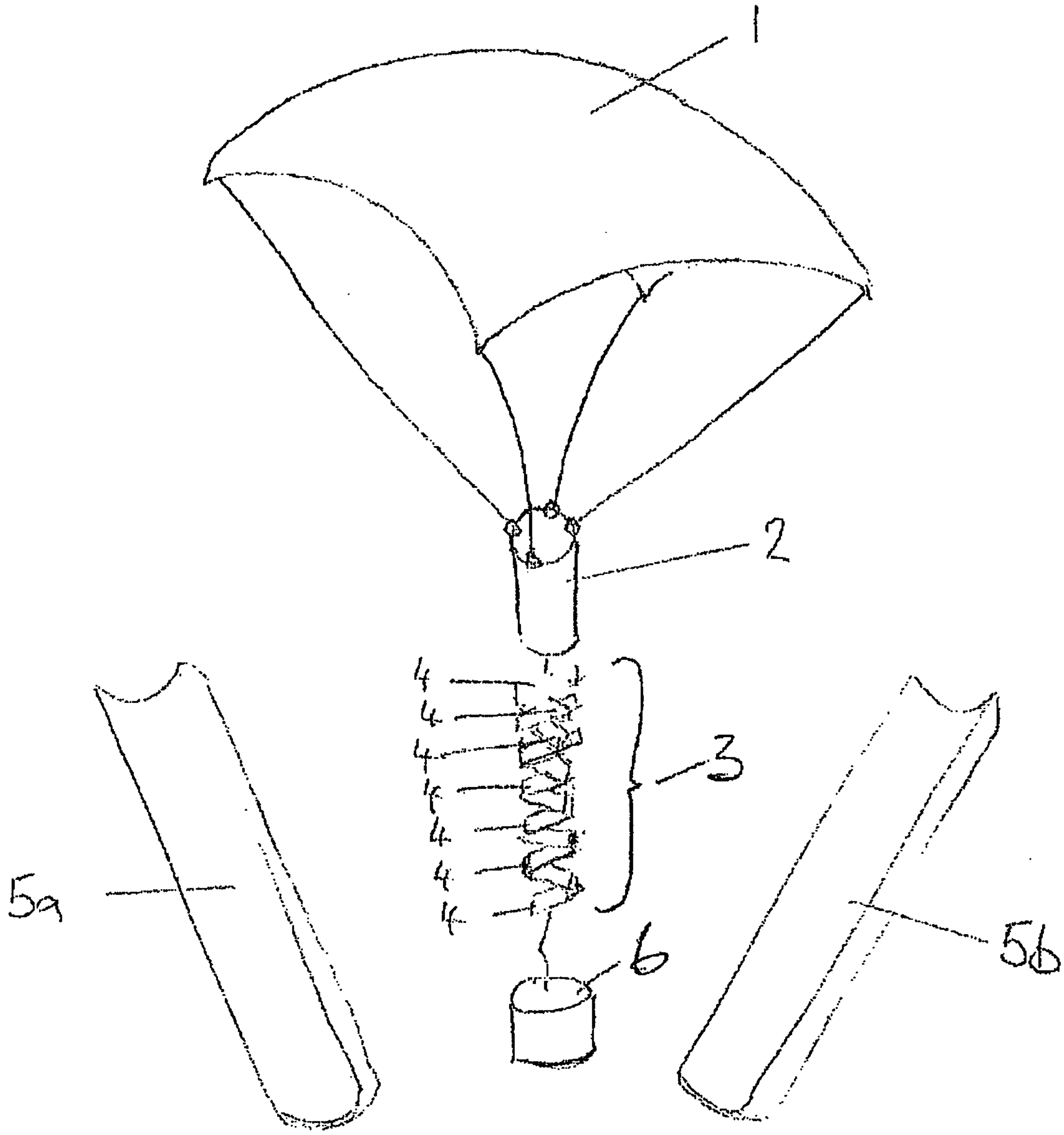


FIG 1

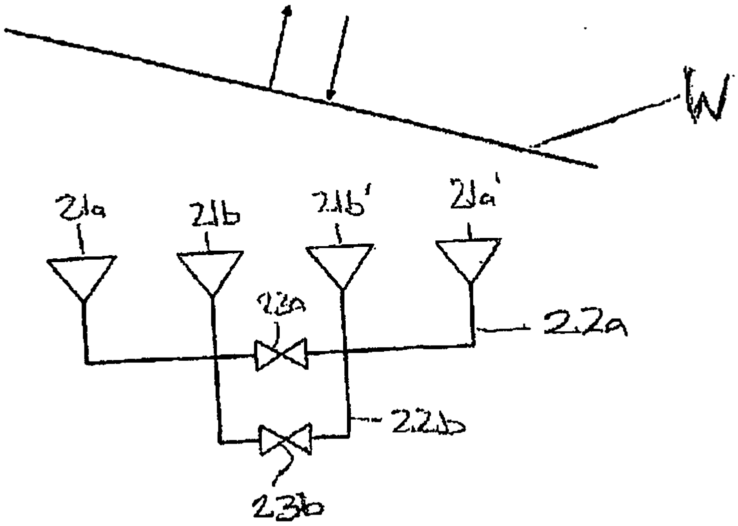
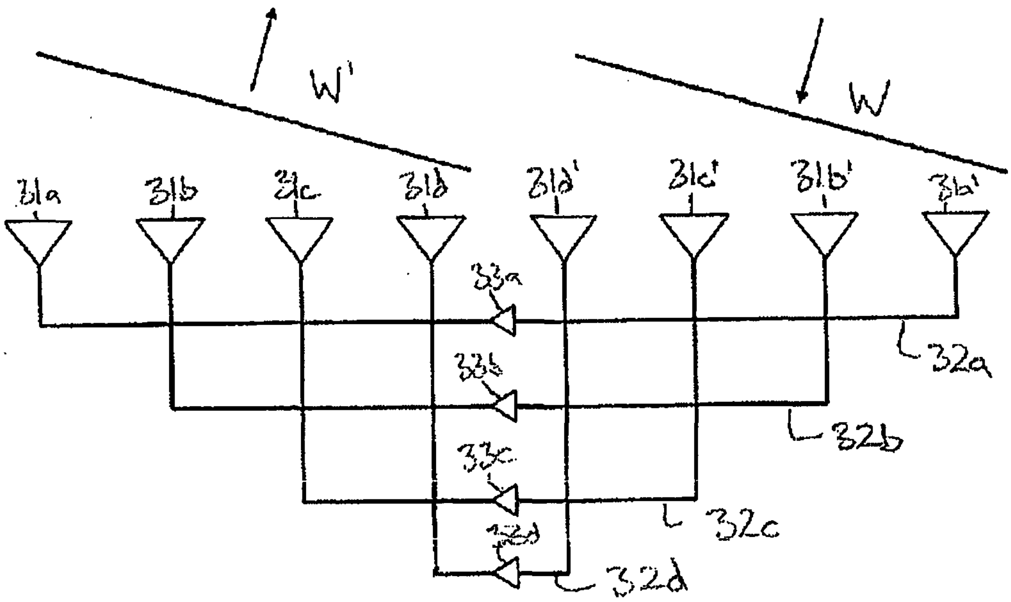

W
21a
21b
21b'
21a'
23a
22a
22b
23b

FIG 2


W'
W
31a
31b
31c
31d
31d'
31c'
31b'
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32b
32c
32d

FIG. 3

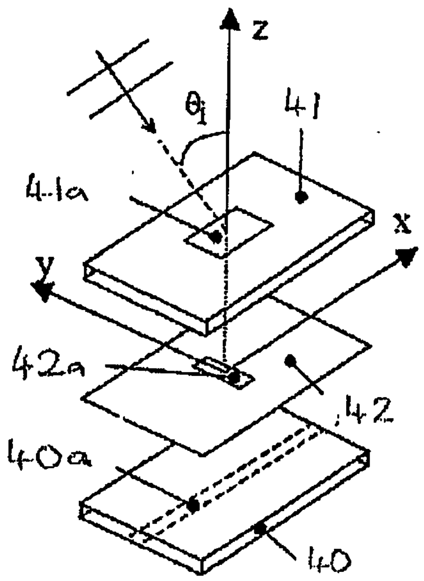

FIG. 4

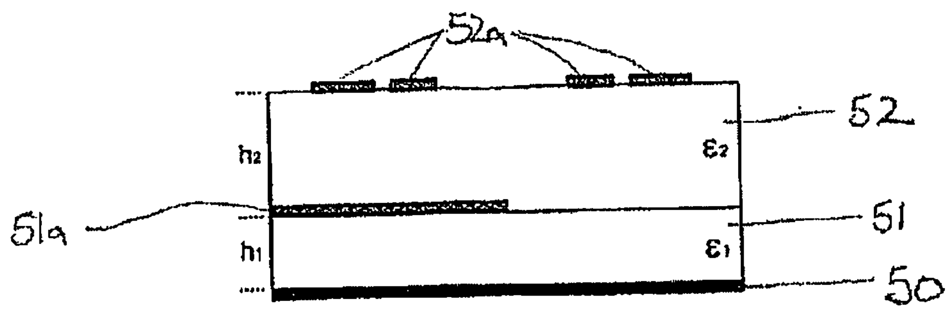

FIG. 5.

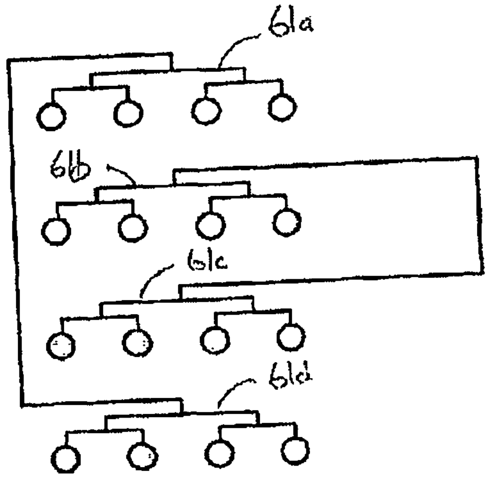

FIG. 6

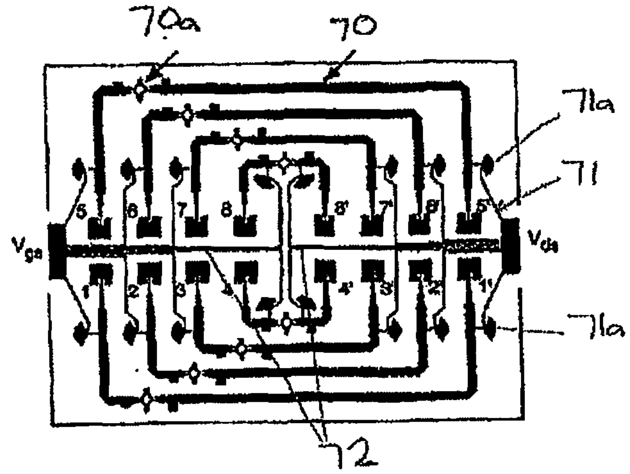

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 10 25 0968

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	FR 2 807 509 A1 (EADS DEUTSCHLAND GMBH [DE]) 12 October 2001 (2001-10-12) * the whole document * -----	1-21	INV. H01Q3/26 H01Q15/16 F41J2/00
Y	US 5 064 140 A (PITTMAN WILLIAM C [US] ET AL) 12 November 1991 (1991-11-12) * the whole document * -----	1-21	
A	HONG TZUNG-JIR ET AL: "24 GHz active retrodirective antenna array" ELECTRONICS LETTERS, IEE STEVENAGE, GB LNKD- DOI:10.1049/EL:19991223, vol. 35, no. 21, 14 October 1999 (1999-10-14), pages 1785-1786, XP006012804 ISSN: 0013-5194 * the whole document * -----	1-21	
A	US 3 938 151 A (TRENAM RICHARD S) 10 February 1976 (1976-02-10) * the whole document * -----	1-21	TECHNICAL FIELDS SEARCHED (IPC) H01Q F41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	27 August 2010	Moumen, Abderrahim

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CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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