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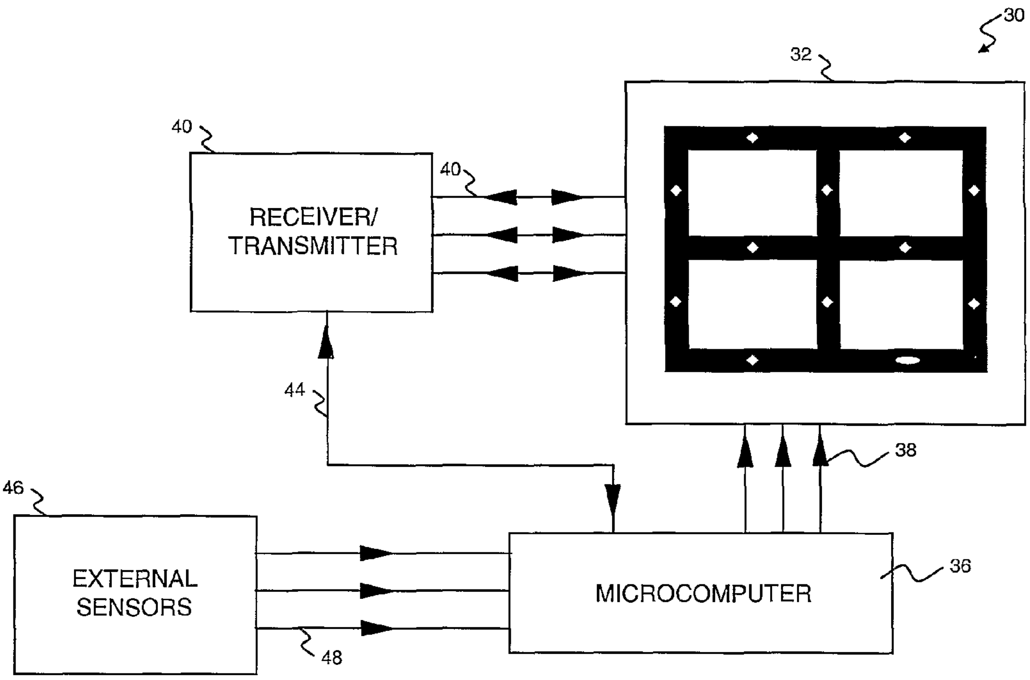
[Continued on next page]

(54) Title: COMPLEMENTARY SELF-STRUCTURING ANTENNA



(57) Abstract: A self-structuring antenna system is provided that employs complementary antenna elements. The self-structuring antenna system includes: a plurality of complementary antenna elements positioned relative to each other in a predetermined orientation; a plurality of switches selectively connecting the plurality of complementary antenna elements so that opening one of the switches operatively couples one complementary antenna element to an adjacent complementary antenna element; and a control device that is responsive to an input signal which causes the control device to open and close the switches based on a predetermined control scheme.

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COMPLEMENTARY SELF-STRUCTURING ANTENNA

FIELD OF THE INVENTION

[0001] The present invention relates generally to a self-structuring antenna and, more particularly, to an antenna system that includes an array of complementary antenna elements selectively connectable to each other to provide different antenna configurations.

BACKGROUND OF THE INVENTION

[0002] Communications systems require antennas that detect electromagnetic radiation at certain frequencies to receive a transmitted signal of interest. Thus, antenna systems are specifically designed to provide a suitable performance for a particular communications system and to operate under specific electrical and/or environmental conditions. Typically, the transmission and reception performance of the antenna system is provided by the configuration of the physical antenna structure. An antenna system may be specifically designed to operate within a specific frequency range, to have a particular radiation/reception pattern, and/or to operate in the vicinity of certain conductive structures, such as automobile bodies. The communications system may require that the antenna system be highly directive, cover a wide range of frequencies, and also provide good performance in particular environmental conditions.

[0003] The design of an antenna system is generally a compromise to accomplish all of these things. Highly directive antennas typically do not give good reception for wide frequency ranges, wide band frequency antennas must be physically pointed to provide suitable directionality, and the performance of antennas designed to operate well in one environmental condition will typically degrade in performance as the environment changes. For example, consider the set of compromises represented by automobile antennas for a vehicle radio. The automobile antenna must be able to operate over the fairly wide FM radio frequency band, must be sensitive to its placement on a large conducting body, and must be able to maintain a strong received signal as the vehicle changes its orientation to the transmitting antenna. A typical vehicle antenna does not perform any of these requirements well, and is only marginally capable in each. This is because once the vehicle antenna is constructed, it is unable to adapt to the changing situation and environment that the vehicle is exposed to.

[0004] A significant improvement in overall antenna performance could be achieved by an antenna that was capable of altering its physical shape in response to a changing electrical and/or physical environment. These types of antenna systems will be generally referred to here as "self-structuring" antenna systems. An exemplary self-structuring antenna is further described in U.S. Patent No. 6,175,723.

[0005] Integrating self-structuring antennas into a motor vehicle is one contemplated application. Typically, the antenna is integrated into the rear window of the motor vehicle. In this configuration, the wire antenna elements of the antenna array are vertically oriented, thereby allowing for reception and transmission of vertically polarized wave. However, it is envisioned that antennas may also be integrated into other parts of the vehicle, such as the roof of the vehicle. In this configuration, the antenna elements cannot be vertically oriented.

[0006] Therefore, it is desirable to provide a self-structuring antenna system having complementary antenna elements, such as slots in a conducting ground plane. In this way, the improved self-structuring antenna system is operable to receive and transmit vertically polarized waves when oriented in a horizontal position.

SUMMARY OF THE INVENTION

[0007] In accordance with the present invention, a self-structuring antenna system is provided that employs complementary antenna elements. The self-structuring antenna system includes: a plurality of complementary antenna elements positioned relative to each other in a predetermined orientation; a plurality of switches selectively connecting the plurality of complementary antenna elements so that opening one of the switches operatively couples one complementary antenna element to an adjacent complementary antenna element; and a control device that is responsive to an input signal which causes the control device to open and close the switches based on a predetermined control scheme.

[0008] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a plan view of an exemplary antenna array of complementary antenna elements for use in a self-structuring antenna system in accordance with the present invention;

[0010] Figure 2 is a block diagram of a basic self-structuring receiving/transmitting antenna system according to the present invention; and

[0011] Figure 3 is a plan view of an exemplary antenna structure for use in a self-structuring antenna system according to an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Figure 1 shows a plan view of an exemplary antenna array 10 in accordance with the present invention. The antenna array 10 includes a series of interconnected complementary antenna elements 12 defining a rectangular array. More specifically, the antenna array includes slots 14 formed in a conductive material 16. For illustration purposes, the antenna array 10 includes nine slots 14. However, as will be appreciated by those skilled in the art, the number of complementary antenna elements 12 in the array 10 would depend on the particular design and use for an antenna system that incorporated the antenna array 10. The slots may be any suitable dimensions for a certain application and may be formed in any suitable conductive material. It is also envisioned that the complementary antenna elements may also be used in combination with conventional antenna elements (e.g., wires) to construct the antenna array.

[0013] The array of complementary antenna elements 12 is configured such that each slot 14 may be selectively coupled to one or more adjacent slots 14. Slots 14 are coupled by a controllable switch junction 18 which is placed across the slot gaps. The switch junctions 18 represent any suitable switch device, for example, a mechanical device such as a relay, or an electrical device, such as solid-state relay or solid-state switch. Each switch junction 18 is controllable such that it can be open-circuited (opened) or short-circuited (closed) by a predetermined control signal, for example from an embedded microcomputer, to selectively couple various complementary antenna elements 12 into different configurations. In other words, opening a controllable junction operably couples two adjacent slots, thereby defining a longer slot region. On the other hand, closing a controllable junction creates a short circuit between two adjacent slots, thereby defining a shorter slot region. This provides the self-structuring feature of the antenna array 10 that allows the array 10 to change its physical shape. By choosing which junctions 18 are closed, a wide variety of different physical antenna shapes can be provided. Note that antenna elements 12 need not be physically connected to other antenna elements 12 to affect the performance of the antenna array 10. Each element 12 forms part of the array 10, whether it is operatively coupled to adjacent elements 12 or not. Thus, parasitic arrays and parasitic tuning stubs are provided, and possible configurations include classic Yagi-Uda arrays.

[0014] An antenna feed structure 20, including at least one feed point taken across a slot gap, forms part of the array 10 that connects the array 10 to receiving circuitry to process the received signal. The feed structure 20 can be attached to the antenna array 10 at any convenient or desirable location in accordance with the design of the antenna system. Multiple feed points are possible, and can be used to control multi-path ghosting and fading. This allows the antenna receiver to distinguish several versions of the same signal arriving from several different directions. The size of the complementary antenna elements 12, and the length of the slot regions in the array 10 would depend on the particular design of the antenna system, and the frequency band of interest being received. As would be appreciated by those skilled in the art, the specific configuration of the array 10 would be based on the particular application.

[0015] Control lines used to control the switching of the junctions 18 may be embedded within a skeletal support structure, such as a plastic structure or a simple wire harness. Ordinarily, the interaction of the antenna support structure holding the control lines would be a serious design consideration for an existing antenna structure, but the nature of the self-structuring antenna system of the invention would allow it to automatically compensate for such interactions. However, if these interactions proved to be too severe, a fiber optic cable, or an embedded fiber optic channel, could be used to carry the control signals to opto-electronic switches at the junctions 18.

[0016] Figure 2 shows a block diagram of a basic self-structuring receiving/transmitting antenna system 30 suitable for use with the present invention. The antenna system 30 includes an antenna array 32 of the type described above with reference to Figure 1. The antenna array 32 includes a plurality of complementary antenna elements that are selectively connectable in the manner as discussed above. A microcomputer 36 provides electrical control signals on control lines 38 that selectively open and close the switch junctions between the elements in accordance with the performance of the antenna system 10. The microcomputer 36 can be any suitable microcomputer known in the art that provides the necessary control function for the antenna system 30, and is unobtrusive to the antenna design. The microcomputer 36 is programmed with a suitable algorithm to control the switch junctions between the elements in accordance with a particular antenna performance optimization scheme.

[0017] The electromagnetic signals received by the antenna array 32 are collected by feed lines 40 connected to the array 32 at a suitable location. Each feed line 40 represents a pair of feed lines connected to a particular location in the array 32 to collect the received signal. The signals on the feed lines 40 are sent to a receiver 42 to process the signals depending on the particular application. The receiver 42 can be any suitable receiver for the purposes described herein, and is selected based on the particular use of the antenna system 30. A performance signal on a feedback control line 44 from the receiver

42 is applied to the microcomputer 36 to provide an indication of the reception performance of the antenna array 32. The performance signal from the receiver 42 can be any signal that represents the reception performance of the antenna array 30, such as a signal strength signal, an audio clarity signal, etc.

[0018] The antenna system 30 can also be used as a transmitting system. When used as a transmitting system, the receiver/transmitter 42 generates a signal to be transmitted that is applied to the antenna array 32 on the feed lines 40. As with the discussion of the system 30 being used to receive signals, the physical configuration of the antenna array 32 can be altered to provide the transmitting performance desired, such as directionality. The performance of the transmitting antenna array 32 can be controlled by providing a feedback signal from a plurality of external sensors 46 placed in the near zone field of the antenna array 32 to the microcomputer 36. The sensors 46 can be any suitable sensor known in the art that is responsive to the transmitted signal from the antenna array 32, and that provides an indication of signal strength, direction, etc. of the transmitted signal. The feedback signal indicative of the transmitted signal is sent to the microcomputer 36 on control lines 48.

[0019] The success of a self-structuring antenna array of the type described in connection with this invention is highly dependent on the algorithms used to operate the microcomputer 36. A fuzzy control system can be used when several performance qualities are desired, such as high signal strength, good audio clarity, efficient multipath suppression, etc. A trade-off exists between the diversity of the antenna system, the number of possible configurations allowed by the antenna structure, and the complexity of searching for the optimum structural arrangement. An antenna system with a higher level of diversity (more antenna elements and junctions) should provide a more optimal performance, but will require a longer time to find that optimum configuration. Obviously, even a fast microcomputer cannot sort through an excessively large number of possibilities in any practical real-time application. The greatest benefit of the self-structuring skeleton approach is that the optimization is binary, where each junction 18 is either on or off. Many recently developed algorithms can be used to optimize the antenna structure without exhaustively searching all possibilities. Two of the most promising algorithms currently available are genetic algorithms and simulated annealing algorithms.

[0020] The self-structuring antenna of the invention offers significant improvements over existing antenna systems because of its inherent versatility. It is not necessary to actually know the best configuration of the antenna array for a particular application. The inherent design and the algorithm used in the microcomputer 36 will determine the best configuration based on the reception. In alternate antenna designs, the antenna elements can be different structures besides cross-wire elements. The antenna arrays of the invention can be comprised of any connectable complementary antenna element design known in the art. The antenna system can be a wide band antenna system because the structure may be altered in response to frequency changes to provide an optimum impedance match. At the same time, the antenna can respond to changes in physical orientation and environmental conditions. For example, it can adapt to the orientation of an automobile as it turns a corner, or the position of a cellular phone as its user moves his body or the way in which he is holding the phone. It can also adapt to the presence of rain, fog or even immersion in water.

[0021] The basic structure of the antenna array 10 shown in Figure 1 has symmetry. Because of this, the different combinations of opened and closed junctions 18 may provide a wide degree of redundancy for the many configurations. This may lead to needless searching for the optimization for a particular reception by the microcomputer 36, and thus a waste of system resources. Figure 3 shows a plan view of an antenna array 50 including a series of complementary antenna elements 52 separated by controllable switch junctions 54. As is apparent, the orientation of the junctions 54, and the differing lengths of the various complementary antenna elements 52 provides for different antenna configurations, where the closing of one or more of the junctions 54 does not match the closing of another one or more of the junctions 54. In other words, each configuration of complementary antenna elements based on different closing arrangements of the junctions 54 creates a different antenna configuration. Further, the differing lengths of the complementary antenna elements 52 provides for a wider range of frequencies.

[0022] As mentioned above, the use of slots as the complementary antenna elements in the antenna array is by way of example in that virtually any type of antenna element can be used within the scope of the invention. Of course, other antenna element shapes and designs can be used within the scope of the present invention. The shape of the arrays 10 and 32 above is rectangular. However, other configurations for the arrays 10 and 32 may be better for different applications. A less geometrically-uniform skeletal structure may be useful for embedding antennas within electronic systems and their containers. For example, a skeletal structure could be incorporated into the plastic cabinet of a television set or within the plastic casing of a cellular telephone. The skeletal configuration could take on whatever shape is convenient. Malleable, plastic-based skeletal sheets would provide a flexible technique of applying self-structuring antennas to a wide variety of geometrical conditions.

[0023] The simple skeletal antenna structure of the antenna system of the invention has various applications that will improve antennae performance. For example, a simple to use indoor TV antenna is easy to implement through a structure built into the plastic console. A skeletal structure antenna array can be included in each of the console walls and fed to the antenna receiver. When the channel is changed, the structure can be changed to provide both signal strength and picture clarity. To design a fixed antenna to operate within the console would be very difficult, due to the unpredictable interactions with the electrical components inside the TV. However, by its very nature, the self-structuring antenna system of the invention will adapt to provide the best possible design as dictated by the chosen feedback signals. Thus, very little specific design is required.

[0024] The skeletal structure of the antenna array of the invention will also offer increased performance for other types of antenna systems. For example, an automobile antenna using the design of the invention would adapt itself to both the presence of the automobile body and the constantly changing orientation of the arriving electromagnetic signal. Additionally, for cellular telephone use, because different users couple to the antenna of the cellular phones differently, and the users are constantly in motion, and users are often in environments subject to multi-path and fading, the self-structuring antenna system of the invention can respond quickly to such a changing environment.

[0025] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A self-structuring antenna system comprising:

a plurality of complementary antenna elements positioned relative to each other in a predetermined orientation, each of the plurality of complementary antenna elements being selectively coupled to one or more of the other complementary antenna elements;

a plurality of switches selectively connecting the plurality of complementary antenna elements so that opening one of the switches operatively couples one complementary antenna element to an adjacent complementary antenna element; and

a control device controlling each of the switches, said control device being responsive to an input signal that causes the control device to open and close the switches based on a predetermined control scheme.

2. The system according to claim 1 wherein the complementary antenna elements are further defined as slots formed in a conductive material.

3. The system according to Claim 1 wherein closing one of the switches electrically isolates one complementary antenna element from an adjacent complementary antenna element.

4. The system according to Claim 1 wherein the plurality of complementary antenna elements are further defined as slots of differing lengths formed in a conductive material.

5. The system according to Claim 4 wherein the plurality of switches operatively couple adjacent slots such that opening one switch defines a slot region different from the opening of any other switch.

6. The system according to claim 1 wherein the input signal is generated by a receiver connected to the complementary antenna elements, said

receiver generating the input signal based on a signal received by the antenna system.

7. The system according to claim 6 wherein the input signal is indicative of reception performance of the antenna system.

8. The system according to claim 1 wherein the control device is an embedded microcomputer that is run by an antenna algorithm that controls the closing and opening of the plurality of switches.

9. The system according to claim 1 further comprising at least one external sensor, said at least one external sensor outputting a signal to the control device to provide an indication of an external condition.

10. The system according to claim 1 wherein the switches are selected from the group consisting of mechanical relays, solid-state relays and opto-electronic relays.

11. The system according to claim 1 further comprises at least one antenna element positioned relative to the plurality of complementary antenna elements and cooperably operable therewith.

12. A self-structuring antenna system for optimizing the reception or transmission performance of an antenna, said system comprising:

a plurality of complementary antenna elements defining an antenna array, said antenna array being responsive to an electromagnetic signal;

a plurality of controllable switches selectively connecting the plurality of antenna elements, wherein the switches are selectively opened to operatively couple at least two of the complementary antenna elements in the array;

at least one of a receiver or a transmitter electrically connected to the antenna array at least one feed point, said receiver being responsive to the signal from the antenna array and generating an input signal based on the electromagnetic signal received by the antenna array, said transmitter generating the signal being transmitted from the antenna array; and

a control device controlled by an antenna algorithm, said control device being responsive to the signal from the at least one receiver or transmitter, and controlling the plurality of switches to vary the electrical configuration of the antenna array to optimize the performance of the antenna system.

13. The system according to claim 12 wherein the complementary antenna elements are further defined as slots formed in a conductive material.

14. The system according to claim 12 wherein the plurality of complementary antenna elements are further defined as slots of differing lengths formed in a conductive material.

15. The system according to claim 14 wherein the plurality of switches operatively couple adjacent slots such that opening one switch defines a slot region different from the opening of any other switch.

16. The system according to claim 12 wherein the control device is an embedded computer.

17. The system according to claim 12 wherein the switches are selected from the group consisting of mechanical relays, solid-state relays and opto-electronic relays.

18. A self-structuring antenna system comprising:

a plurality of complementary antenna elements positioned relative to each other and defining an antenna array, each of said complementary antenna elements being selectively coupled to one or more of the other complementary antenna elements;

a plurality of switch means for selectively connecting the plurality of antenna elements so that opening one of the switches operatively couples one complementary antenna element to an adjacent complementary antenna element; and

a control means for controlling each of the switch means, said control means being responsive to an input signal that causes the control means to open and close the switch means based on the reception performance of the antenna system.

19. The system according to claim 18 wherein the complementary antenna elements are further defined as slots formed in a conductive material.

20. The system according to claim 18 wherein the plurality of complementary antenna elements are further defined as slots of differing lengths formed in a conductive material.

21. The system according to claim 18 further comprising a receiver means for receiving a signal from the antenna array, said receiver means generating the input signal.

22. The system according to claim 18 further comprising a transmitter means for transmitting a signal from the antenna array and a sensor generating an input signal describing performance of the antenna array.

23. An automotive vehicle, comprising:

a self-structuring antenna subsystem associated with the vehicle and further comprising:

a plurality of complementary antenna elements defining an antenna array, said antenna array being responsive to an electromagnetic signal, a plurality of controllable switches selectively connecting the plurality of complementary antenna elements, wherein the switches are selectively opened to operatively couple at least two of the complementary antenna elements in the array, and

a control device configured to control each of the plurality of switches in accordance with an antenna algorithm; and

a communication device residing in the vehicle and electrically connected to the antenna array.

24. The automotive vehicle of Claim 23 wherein the complementary antenna elements are further defined as slots in a conductive material.

25. The automotive vehicle of Claim 23 wherein the switches are selectively closed to electrically isolate at least one complementary antenna element from an adjacent complementary antenna element.

26. The automotive vehicle of Claim 23 wherein the antenna array is orientated horizontally.

27. The automotive vehicle of Claim 23 wherein the antenna array is integrally formed in a roof of the vehicle.

28. A consumer electronic device, comprising:

a self-structuring antenna subsystem associated with the device and further comprising:

a plurality of complementary antenna elements defining an antenna array, said antenna array being responsive to an electromagnetic signal,

a plurality of controllable switches selectively connecting the plurality of complementary antenna elements, wherein the switches are selectively opened to operatively couple at least two of the complementary antenna elements in the array, and a control device configured to control each of the plurality of switches in accordance with an antenna algorithm; and

a communication device residing in the device and electrically connected to the antenna array.

29. The consumer electronic device of Claim 28 wherein the complementary antenna elements are further defined as slots in a conductive material.

30. The consumer electronic device of Claim 28 wherein the switches are selectively closed to electrically isolate at least one complementary antenna element from an adjacent complementary antenna element.

31. The consumer electronic device of Claim 28 wherein the antenna array is integrally formed in a housing of a television.

32. A cellular telephone, comprising:

a self-structuring antenna subsystem associated with the telephone and further comprising:

a plurality of complementary antenna elements defining an antenna array, said antenna array being responsive to an electromagnetic signal,

a plurality of controllable switches selectively connecting the plurality of complementary antenna elements, wherein the switches are selectively opened to operatively couple at least two of the complementary antenna elements in the array, and

a control device configured to control each of the plurality of switches in accordance with an antenna algorithm; and

a communication device residing in the telephone and electrically connected to the antenna array.

33. The cellular telephone of Claim 32 wherein the complementary antenna elements are further defined as slots in a conductive material.

34. The cellular telephone of Claim 32 wherein the switches are selectively closed to electrically isolate at least one complementary antenna element from an adjacent complementary antenna element.

35. The cellular telephone of Claim 32 wherein the antenna array is integrally formed in a housing of the telephone.

36. A method for configuring an antenna, comprising:

arranging a plurality of complementary antenna elements relative to each other in a predetermined orientation;

interconnecting the plurality of complementary antenna elements with a plurality of controllable switches such that opening one of the switches couples at least one complementary antenna element to an adjacent complementary antenna element, wherein selectively coupled complementary antenna elements defines an antenna array; and

controlling at least one of the switches to alter the configuration of the antenna array.

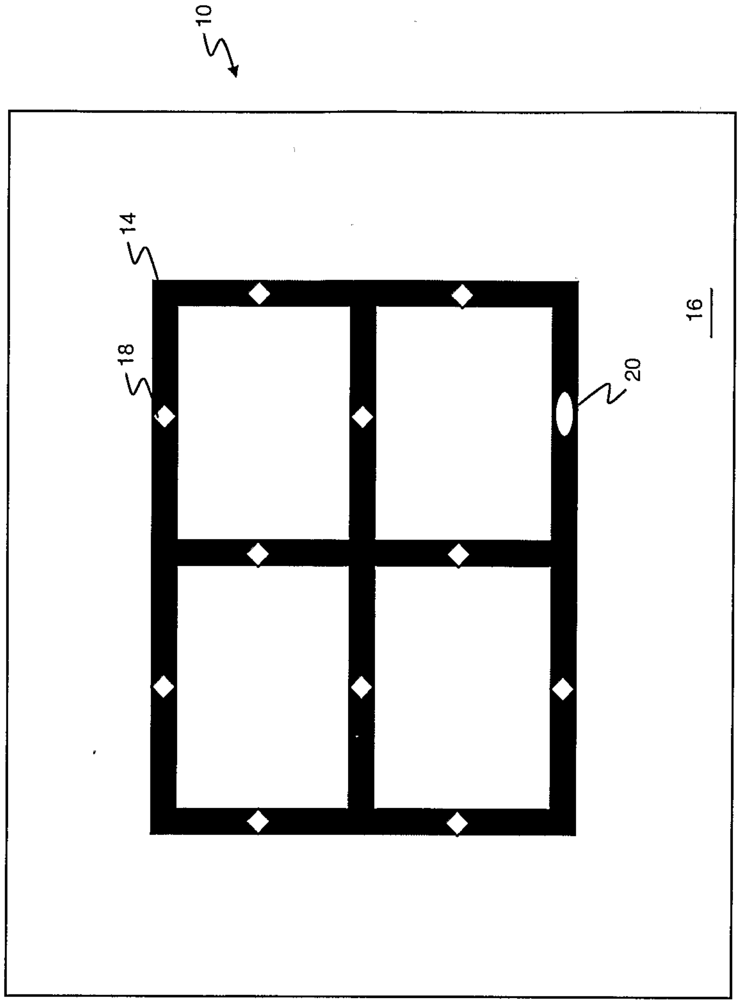
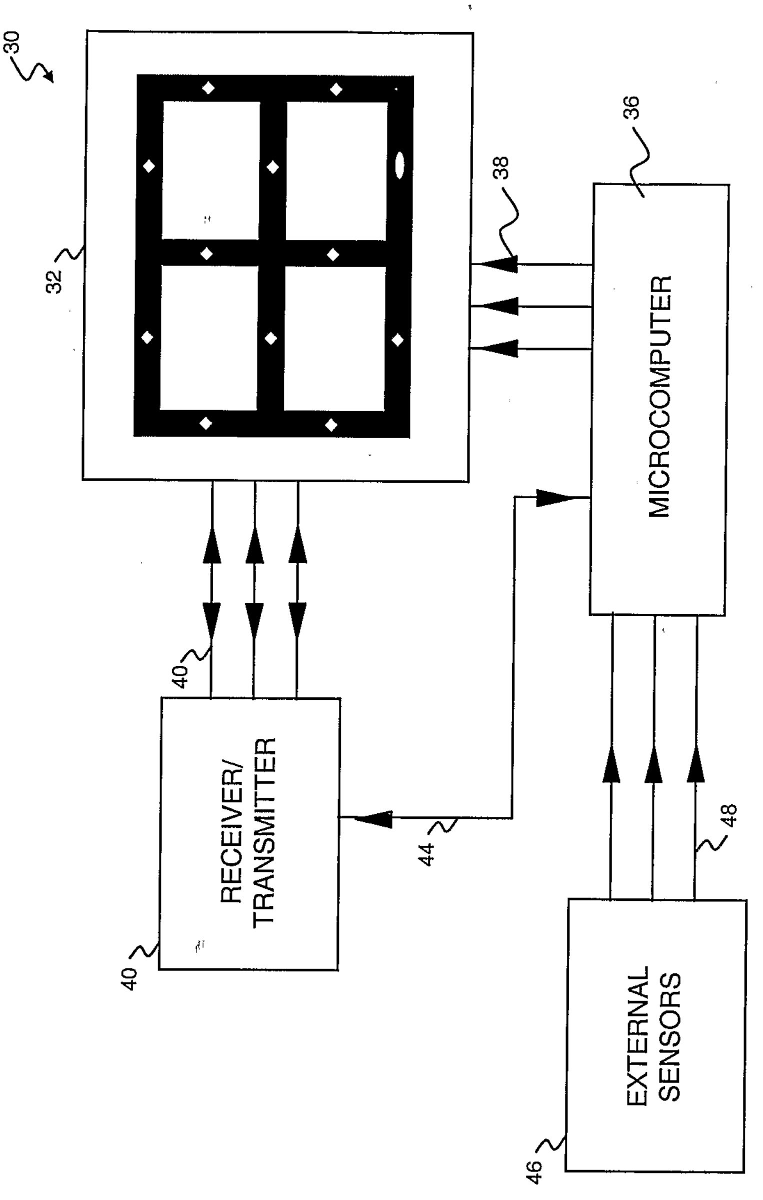


FIG. 1


30
32
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36
MICROCOMPUTER
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RECEIVER/
TRANSMITTER
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48
EXTERNAL
SENSORS
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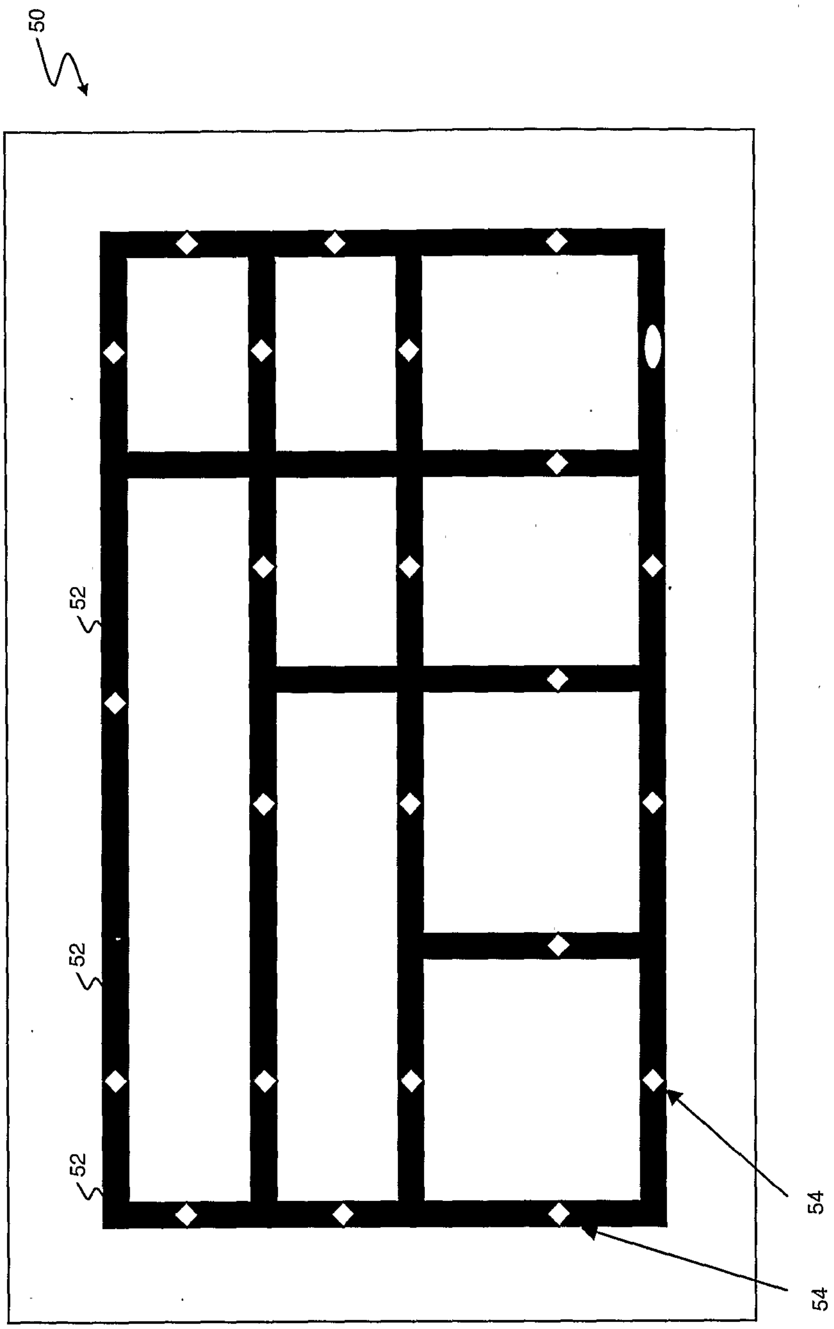
FIG. 2

FIG. 3



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q3/24 H01Q21/06 H01Q1/32 H01Q1/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	SCHAFFNER J H ET AL: "Reconfigurable aperture antennas using RF MEMS switches for multi octave tunability and beam steering" ANTENNAS AND PROPAGATION SOCIETY INTERNATIONAL SYMPOSIUM, 2000. IEEE JULY 16-21, 2000, PISCATAWAY, NJ, USA,IEEE, vol. 1, 16 July 2000 (2000-07-16), pages 321-324, XP010513908 ISBN: 0-7803-6369-8 the whole document ----- -/--	1-36

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2005	05/04/2005

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

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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