159159

A DIRECTIONAL ANTENNA SYSTEM AND A METHOD FOR PRODUCING A PREDETERMINED BEAM PATTERN FOR A DIRECTIONAL ANTENNA

Field of the Invention

The present invention relates to a directional antenna system and a method for producing a predetermined beam pattern for a directional antenna.

Background of the Invention

There are two types of conventional antennae in terms of directionality. One type is an omni-directional antenna which transmits/receives energy to and from its surroundings and is equally sensitive to signals in any direction in its polarization plane, that is a plane perpendicular to the longitudinal axis of the antenna, when the antenna is a horizontal polarization antenna.

Another type of antenna is the directional antenna which transmits/receives energy to and from certain directions only. Due to the narrow beam width used in directional antenna systems, the directional antenna is usually more complex and expensive than the omni-directional antenna.

Conventional directional antennae may improve considerably system performance, for example, when it is necessary to distinguish between several received signals. Also, once the signal direction has been determined, undesirable interference signals can be rejected, so improving the quality of the required signal and thereby improving system performance.

Two types of conventional directional antennae are widely used. One type of directional antenna is the specially designed physical directional antenna and the other is an array-based directional antenna. The array-based directional antenna consists of many antenna elements with certain geometric alignment forming an array of antenna elements. In such an array, one antenna element can be either an omni-directional or a directional antenna. The

G00002

conventional array-based directional antenna is generally more expensive and of a larger size than a conventional physical antenna.

In practice, it is often necessary to change the transceiving direction of the antenna quickly. A single physical directional antenna must be rotated mechanically and, as such, the action is generally slow. By contrast, an array-based directional antenna may change the transceiving direction by means of a beam-forming algorithm which may be achieved relatively quickly using electrical means. However, such a conventional array-based antenna is highly complex and costly.

Thus, there is a need for a directional antenna which can change both the beam direction and radiation pattern very quickly and which is also smaller and cheaper than a conventional array-based antenna.

Summary of the Invention

In general terms, the present invention comprises a directional antenna system comprising an omni-directional antenna surrounded by a number of active absorber elements.

In the context of the present invention, the term 'omni-directional antenna' is to be understood as having its usual meaning in the art, namely, an antenna having equal sensitivity in all directions in its polarization plane, that is, a plane perpendicular to the longitudinal axis of the antenna, when the antenna is a horizontal polarization antenna.

According to a first aspect of the present invention there is provided a directional antenna system having a beam pattern for controlling directional sensitivity of said directional antenna system, the directional antenna system comprising:

an omni-directional antenna, and

one or more active absorbers, wherein said one or more active absorbers are arranged around said omni-directional antenna, and wherein said one or more active absorbers are switchable between an off state and an on state to vary said beam pattern.

According to a second aspect of the present invention there is provided a method for producing a predetermined beam pattern for a directional antenna, comprising the steps of:

positioning one or more active absorbers around an omni-directional antenna, and

switching one or more of said one or more active absorbers between an off state and an on state to produce a predetermined beam pattern.

A preferred embodiment of the present invention may be utilised, for example, in positioning systems to change both beam direction and beam pattern flexibly and swiftly compared to the conventional method of mechanically rotating a directional antenna. Also, auxiliary directional information may be acquired to enhance accurate positioning capability. A preferred embodiment of the invention may also assist in reducing the adverse effects due to multiple reflections or multiple access interferences, for example, in communication and positioning systems.

A directional antenna system according to a preferred embodiment of the invention may be smaller and far less expensive than a conventional array antenna.

Brief description of the drawings

The present invention will now be described by way of example and with reference to the accompanying drawings in which:

Figure 1a is a schematic diagram of the structure of a conventional active absorber;

Figure 1b is a spectrum in the frequency domain of an active absorber of the type shown in Figure 1a;

Figure 2a is a schematic representation of the structure in an active absorber-based directional antenna with common absorbers for both the transmitting and receiving antennae elements according to an embodiment of the invention;

Figure 2b is a plan view of the structure of Figure 2a;

Figure 2c is a schematic representation of the structure in an active absorber-based directional antenna with independent absorbers for both the transmitting and receiving antennae elements according to a further embodiment of the invention;

Figure 2d is a plan view of the structure of Figure 2c;

Figure 3a is a beam pattern of a directional antenna according to an embodiment of the invention comprising active absorbers having a single directional beam;

Figure 3b is beam pattern of a directional antenna according to a further embodiment of the invention comprising active absorbers having two directional beams;

Figure 4a is a schematic diagram of the structure of a multi-layer active absorber according to an embodiment of the invention; and

Figure 4b is a spectrum in the frequency domain of a multi-layer active absorber of the type shown in Figure 4a.

Description of Preferred Embodiments

Certain materials may absorb selectively input microwave energy by electrical means. A device containing such materials may be termed an active absorber. The most common structure of an active absorber is a frequency selective surface (FSS) 1, and this structure is shown in Figure 1a. The structure shown in Figure 1a comprises a number of specifically designed loops 2 with tunable surface-mount reactive lumped element components 3 on a face 4 of the FSS 1. Although each of the components 3 has two electrodes 5, the electrodes are connected in parallel. Thus, there are only two electrodes for the FSS 1.

The band-stop frequency (notch frequency) of the FSS 1 may be changed by varying the bias voltage applied between the two electrodes 5 of the FSS 1. For example, if two bias voltage values v1 and v2 are considered on the FSS 1, bias voltage v1 tunes the notch frequency of the FSS 1 at the center frequency of the signal working spectrum so that the input signal energy to the absorber may mostly be exhausted in the loops 2. Hence, there is almost no signal energy passing through the absorber. In this condition, the absorber absorbs the energy in the working frequency range. This state of the active absorber may be regarded as "switched on".

Bias voltage v2 shifts the notch frequency of the FSS 1 far from the working frequency range. In this condition, although there will still be some small absorption of energy within the working frequency range, the majority of the signal in this range will pass through the absorber. The active absorber is now transparent to the signal and may be regarded as being in the "switched off" state.

Figure 1b shows the spectrum in the frequency domain of an active absorber of the type shown in Figure 1a. It will be seen that at certain voltages, the attenuation of the signal through the active absorber is increased considerably

as the signal is absorbed by the active absorber. This is shown as a notch 6, 8 in the spectrum of Figure 1b. In the switched on state, at a bias voltage of v1, the notch 6 is situated within the working frequency range 9 of the system. When the bias voltage is changed to v2, that is where the active absorber is in the switched off state, the notch 8 falls outside the working frequency range of the system to allow energy to pass through the active absorber.

Figures 2a and 2b show the structure of an absorber-based directional antenna according to a preferred embodiment of the invention. Two omni-directional antennae, one being a transmitter 10 and the other being a receiver 12, are mounted one above the other on a common axis 14 and are separated along the axis by an isolator element 16. A number N of active absorbers 18 are mounted symmetrically around the common axis 14 of these antennae 10, 12. A number M of the active absorbers 18 are switched off where M is in the range of 1 to N, the remaining active absorbers 18 being switched on.

The signal energy may pass along the direction in which the active absorbers 18 are switched off and hence the antenna beam pattern of both antennae 10, 12 is determined by the number of absorbers M which are switched off. The switched off active absorbers 18 may be arranged adjacent to one another or separated by a number of switched on active absorbers 18, depending on the beam pattern required.

It should be noted that, in Figures 2a and 2b, the omni-directional transmitter 10 and receiver 12 antennae are placed along the same vertical axis 14. It is assumed that both the transmitter 10 and receiver 12 antennae are horizontally polarised and hence energy leakage along the vertical axis 14 is very small. It is also assumed that the isolator element 16 between the transmitter 10 and receiver 12 antennae will block small energy leakage between them.

Figures 2c and 2d show the structure of an absorber-based directional antenna according to an alternative preferred embodiment of the invention in which the beam patterns for the transmitter and receiver antennae may be controlled independently. Two omni-directional antennae, one being a transmitter 20 and the other being a receiver 22, are mounted one above the other on a common axis 24 separated by an isolator element 26. Each antenna 20, 22 is surrounded by a group of active absorbers 28, 29, and the two groups of active absorbers 28, 29 are isolated from each other. The antenna beam pattern of both antennae 20, 22 may be determined by the number M of absorbers 28, 29 which are switched off and their positions. The groups of absorbers 28, 28 surrounding the transmitting and receiving antennae 20, 22 may be controlled independently so that the beam patterns for the antennae may differ from each other and be controlled separately.

Figures 3a and 3b illustrate a number of beam patterns 30, 32, 34 which may be obtained from the directional antennae of Figures 2a and 2c. Various other beam patterns may be obtained by switching the active absorbers 18, 28, 29 on and off in different configurations.

Figure 3a illustrates the beam pattern 30 resulting from one or more adjacent active absorbers being in the switched off state, the remaining active absorber(s) being in the switched on state, thus producing a radiation pattern 30 having a single main lobe.

Figure 3b illustrates the beam patterns 32, 34 resulting from two separated groups, each group having one or more adjacently located active absorbers in the switched off state with the remaining absorbers being in the switched on state, thus producing a radiation pattern having two main lobes.

The antenna beam patterns 30, 32, 34 may be controlled in a number of ways, for example:

1. by changing the number of active absorbers 18, 28, 29 which are switched off in one direction, the beam width of the pattern 30, 32, 34 may be altered without changing the direction in which the beam is directed;

2. by changing the locations of the active absorbers 18, 28, 29 which are switched off, but keeping the number of active absorbers which are switched off constant, the direction in which the beam is pointing may be altered, and by altering the number and location of the active absorbers which are switched off, the direction and beam pattern 30, 32, 34 may be altered simultaneously;

3. if it is desired to rotate a narrow beam, this may be achieved by switching off a number of active absorbers 18, 28, 29 sequentially. The switching-off procedure may be as follows:

a. active absorbers 1 through M are switched off and active absorbers M+1 through N are switched on;

b. active absorbers 2 through M+1 are switched off and active absorbers 1 and M+2 through N are switched on; and

c. active absorbers n through M+n-1 are switched off and active absorbers 1 through n-1 and M+n through N are switched on.

If the bandwidth of the signal in use is large, for example, an ultra wide band (UWB) signal, a single layer active absorber as illustrated in Figure 1a may not be able to cover the whole working spectrum. Hence, in a further preferred embodiment, a number of multi-layer active absorber structures of the type shown in Figure 4a may be used as the absorbers for large band width signals in the systems of Figures 2a and 2c.

The multi-layer active absorber structure 38 shown in Figure 4a comprises several single layer active absorbers 40, 42, 44 which may be superposed or

stacked together, each absorber layer 40, 42, 44 being tuned to a different centre frequency. Thus, each absorber layer 40, 42, 44 may be responsible for one part of the signal spectrum and may absorb the signal energy in the respective part of the spectrum. The total absorption region of the frequency spectrum of the multi-layer active absorber 38 will be larger than or equal to the signal spectrum of the directional antenna system into which the multi-layer active absorber structure is incorporated.

Due to fact that the absorber layers 40, 42, 44 are tuning different frequencies, the sizes of the loops associated with each layer will differ from layer to layer and the higher the frequency to be tuned, the smaller the loop required. The bias voltages required may also differ from layer to layer. For example:

If there are K layers, then the corresponding switch on bias voltages may be denoted as v11, ..., v1k. The corresponding switch off bias voltages may be denoted as v21, ..., v2k, so that the resonant frequencies of all layers are tuned out of the working spectrum.

Although the radio-power efficiency of the active absorber-based directional antenna according to an embodiment of the present invention may not be as high as that of a conventional physical directional antenna, this is not important in low radio power systems. In a low radio power system, the radio frequency (RF) power forms just a small part of the total system power.

Figure 4b shows the frequency spectrum of a multi-layer active absorber 38 of the type shown in Figure 4a. It will be seen that when the absorber layer(s) 40, 42, 44 of the multi-layer active absorber 38 are in the switched on state, the central notch frequency f40, f42, f44 for each absorber layer 40, 42, 44 occurs within the working frequency range 46. Thus, with a sufficient number of absorber layers, the entire working frequency range 46 may be covered. When the absorber layer(s) 40, 42, 44 of the multi-layer active absorber 38

are in the switched off state, the central notch frequency for each absorber layer 40, 42, 44 falls out of the working frequency range 46. By altering the bias voltage to the layers, for example by decreasing or increasing the bias voltage, the central notch frequencies Fn may be moved either above or below the working frequency range 46 to allow the signal to pass unattenuated.

In summary, preferred embodiments of the present invention provide a directional antenna system and method of producing a predetermined beam pattern for a directional antenna in which both the beam direction may be altered very quickly compared with conventional methods of mechanically rotating a directional antenna. Furthermore, according to a preferred embodiment of the invention, the beam pattern may also be altered very quickly and flexibly compared with conventional methods. Also, an antenna according to a preferred embodiment of the invention is smaller and more economical than a conventional antenna array beam-forming system.

Embodiments of the present invention may be utilised in positioning systems to change both beam direction and beam pattern flexibly and swiftly, whereby auxiliary directional information may be acquired to enhance accurate positioning capability. Also, preferred embodiments of the invention may assist in reducing adverse effects due to multiple reflections or multiple access interferences in communication and positioning systems.

Various modifications to the embodiments of the present invention described above may be made. For example, other components and method steps may be added or substituted for those above. Thus, although the invention has been described above using particular embodiments, many variations are possible within the scope of the claims, as will be clear to the skilled reader, without departing from the spirit and scope of the invention.

Claims:

1. A directional antenna system having a beam pattern for controlling directional sensitivity of said directional antenna system, the directional antenna system comprising:

an omni-directional antenna, and

one or more number of active absorbers, wherein said one or more active absorbers are arranged around said omni-directional antenna, and wherein said one or more active absorbers are switchable between an off state and an on state to vary said beam pattern.

2. The directional antenna system according to claim 1, wherein the one or more active absorbers are arranged around a longitudinal axis of said omni-directional antenna.

3. The directional antenna system of any one of claims 1 or 2, wherein the omni-directional antenna comprises a transmitter antenna.

4. The directional antenna system of any one of claims 1 or 2, wherein the omni-directional antenna comprises a receiver antenna.

5. The directional antenna system according to any one of claims 1 or 2, wherein the omni-directional antenna comprises a transmitter antenna and a receiver antenna, each of said transmitter and receiver antennae having an associated beam pattern.

6. The directional antenna system according to claim 5, wherein said transmitter antenna and said receiver antenna are arranged adjacent to one another about a common axis and are spaced along said common axis by an insulator element.

7. The directional antenna system according to claim 6, wherein said one or more active absorbers are common to said transmitter antenna and said receiver antenna for controlling simultaneously the beam patterns associated with said receiver and transmitter antennae.

8. The directional antenna system according to claim 6, wherein a first number of said one or more active absorbers are arranged around said transmitter antenna and a second number of said one or more active absorbers are arranged around said receiver antenna for controlling independently the beam patterns associated with said receiver and transmitter antennae.

9. The directional antenna system according to any one of the preceding claims, wherein said beam pattern of said directional antenna system is rotatable by switching said one or more active absorbers on and off in a sequence.

10. The directional antenna system according to any one of claims 1 to 8, wherein said beam pattern of said directional antenna system is alterable by switching said active absorbers on and off in a sequence, wherein said sequence determines a range of radiation patterns obtainable, said range of radiation patterns having one or more main lobes each having an adjustable width for varying sensitivity of said directional antenna system.

11. The directional antenna system according to any one of the preceding claims, wherein said beam pattern of said directional antenna system has an associated beam width, and wherein said one or more active absorbers comprise means for altering said beam width, wherein said means for altering said beam width comprises means for varying the number of active absorbers switched off in a predetermined direction so as to change the beam width in said predetermined direction.

12. The directional antenna system according to any one of the preceding claims, wherein said one or more active absorbers comprise means for altering the direction in which said directional antenna is directed, said means for altering comprising means for varying a predetermined selection of said one or more active absorbers which are in said off state.

13. The directional antenna system according to any one of claims 1 to 8, wherein said beam pattern of said directional antenna system is alterable by switching said active absorbers on and off in a sequence, wherein said sequence comprises:

a. active absorbers 1 through M in the switched off state and active absorbers M+1 through N in the switched on state;

b. active absorbers 2 through M+1 in the switched off state and active absorbers 1 and M+2 through N in the switched on state; and

c. active absorbers n through M+n-1 are in the switched off state and active absorbers 1 through n-1 and M+n through N are in the switched on state.

14. The directional antenna system according to any one of the preceding claims, wherein one or more of said one or more active absorbers comprise a plurality of single layer active absorbers, each layer being tunable to a different frequency within a predetermined working frequency band width.

15. A method for producing a predetermined beam pattern for a directional antenna, comprising the steps of:

positioning one or more active absorbers around an omni-directional antenna, and

switching one or more of said one or more active absorbers between an off state and an on state to produce a predetermined beam pattern.

16. The method according to claim 15, wherein the step of positioning comprises positioning said one or more active absorbers around a longitudinal axis of said omni-directional antenna.

17. The method according to claim 16, further comprising positioning a transmitter antenna and a receiver antenna adjacent to one another about a common axis and spaced along said common axis by an insulator element, wherein said omni-directional antenna comprises said transmitter antenna and said receiver antenna.

18. The method according to claim 17, wherein said receiver antenna and said transmitter antenna each have an associated beam pattern, and wherein the step of switching the states of one or more of said one or more active absorbers comprises controlling simultaneously the beam patterns associated with said receiver and transmitter antennae by switching the state of said one or more active absorbers common to said transmitter antenna and said receiver antenna.

19. The method according to claim 17, wherein the step of positioning comprises positioning a first number of said one or more active absorbers around said transmitter antenna and positioning a second number of said one or more active absorbers around said receiver antenna for controlling independently the beam patterns associated with said receiver and transmitter antennae.

20. The method according to any one of claims 15 to 19, further comprising rotating said beam pattern of said directional antenna by switching said active absorbers on and off in a sequence.

21. The method according to any one of claims 15 to 19, further comprising altering said beam pattern of said direction antenna by switching said active absorbers on and off in a sequence, wherein said sequence determines a range of radiation patterns obtainable, said range of radiation patterns having one or more main lobes each having an adjustable width for varying sensitivity of said directional antenna.

22. The method according to any one of claims 15 to 21, wherein said beam pattern of said directional antenna has an associated beam width, and said method further comprising altering said beam width by varying the number of active absorbers switched off in a predetermined direction so as to change the beam width in said predetermined direction.

23. The method according to any one of claims 15 to 22, further comprising altering the direction in which said directional antenna is directed by varying a predetermined selection of said one or more active absorbers which are in said off state.

24. The method according to any one of claims 15 to 20, further comprising altering said beam pattern of said directional antenna by switching said active absorbers on and off according to the following sequence:

a. switching active absorbers 1 through M to the switched off state and switching active absorbers M+1 through N to the switched on state;

b. switching active absorbers 2 through M+1 to the switched off state and switching active absorbers 1 and M+2 through N to the switched on state; and

c. switching active absorbers n through M+n-1 to the switched off state and switching active absorbers 1 through n-1 and M+n through N to the switched on state.

25. The method according to any one of claims 15 to 24, further comprising forming one or more of said one or more active absorbers of a plurality of single layer active absorbers, each layer being tunable to a different frequency within a predetermined working frequency band width.