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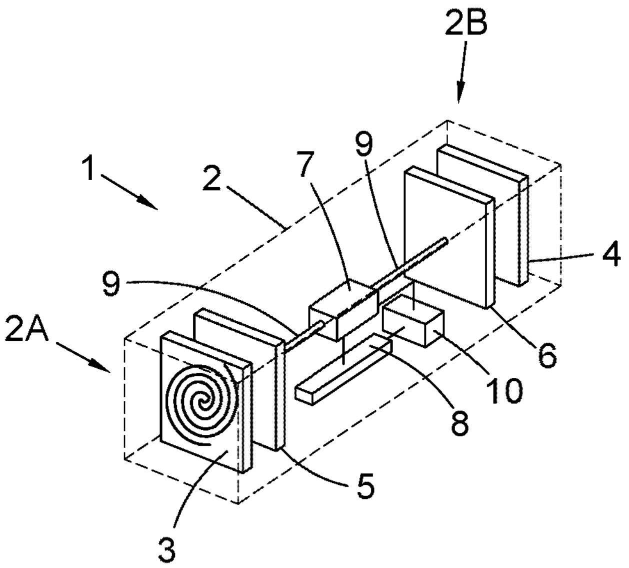

FIG. 1

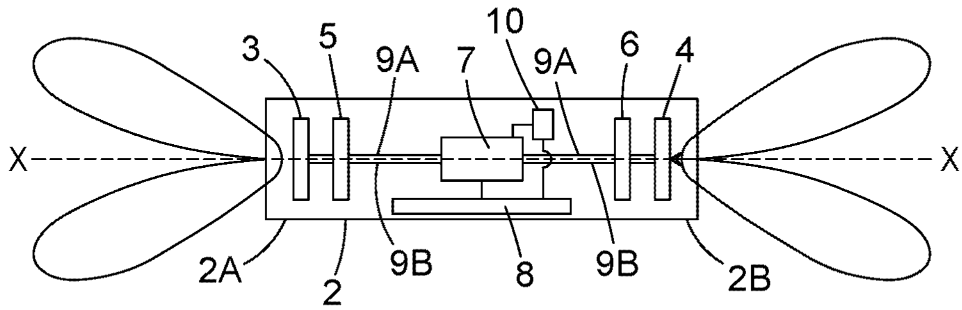

FIG. 2

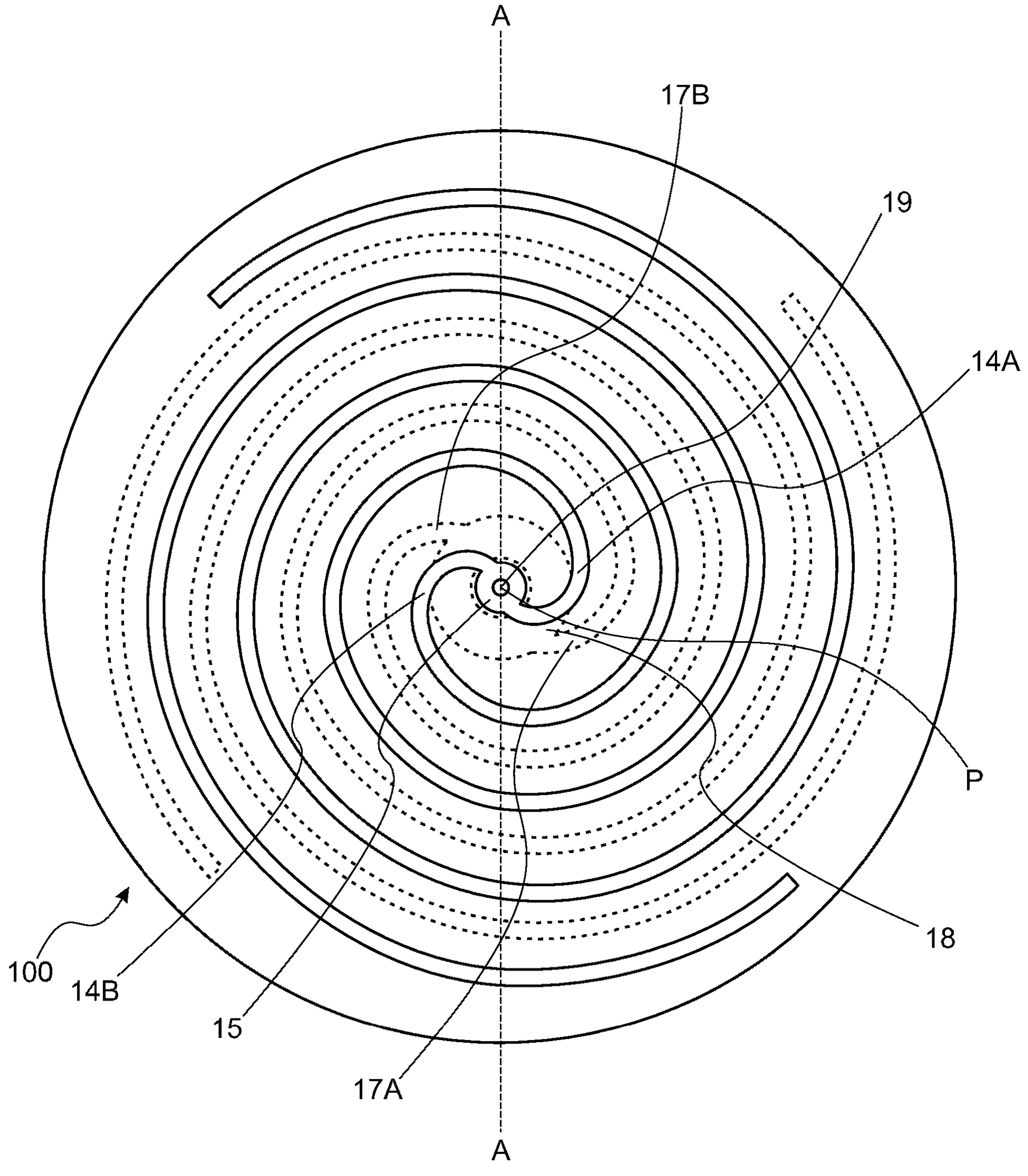

FIG. 3

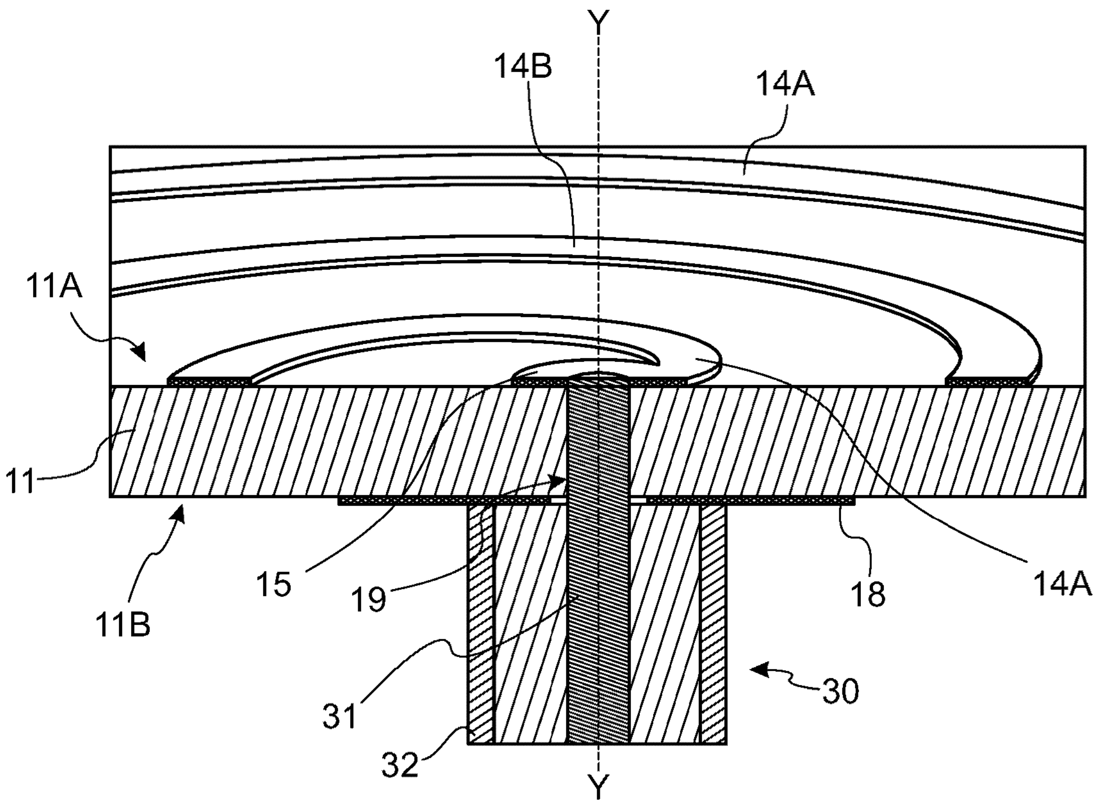

FIG. 4

A Decoy

The present invention relates to an RF decoy for protecting a platform from radar-based threats.

Expendable Active Decoys (EAD) may provide effective protection for platforms against radar-based threats. They are commonly used as seduction devices and can be combined with manoeuvre and chaff deployment to further confuse an adversary radar.

The decoys may be supplied in an expendable standardised chaff/flare cartridge that can be fitted to virtually any military aircraft thereby minimising platform integration costs.

US 8,049,656 B2 relates to an RF decoy having, in one embodiment, two centrally located antennas that have boresights directed broadside to the decoy, one to receive and one to transmit, with an optional third antenna facing forward. The system relies on using the body of the decoy itself as a radiator to broaden the coverage of the first and second antenna.

EP3019819 also describes a known RF decoy.

According to an aspect of the invention there is provided an RF decoy for protecting a platform from threats, the RF decoy having a first end and a second end;

the decoy comprising a first multi-arm planar antenna and a second multi-arm planar antenna, the first antenna located about the first end to radiate, when in use, nominally into a first hemisphere extending beyond the first end of the RF decoy and the second antenna located about the second end to radiate, when in use, in an opposite direction to the first antenna, nominally into a second hemisphere beyond the second end, and wherein the decoy comprises an RF feed system adapted to drive each antenna in a second order mode or higher order mode, such that the beam peak of each antenna is off-boresight.

Placing the antenna toward or at both ends of the decoy makes manufacture of the decoy and the antenna more straightforward compared with placement in a central position.

When operated such that both antennas are either transmitting or receiving at the same time, this positioning of the antennas, in combination with each being driven in a second or higher order mode, provides for substantially omnidirectional coverage around the decoy except along the antenna's respective nominal boresights. Nevertheless, this is not detrimental to performance of the RF decoy, as it has been realised that threats are unlikely to lie along the longitudinal axis of the decoy and so energy directed along the nominal in these directions would be likely to be wasted.

In view of the above, the RF feed system may be adapted to drive the antennas so that both antennas are simultaneously configured to transmit, or simultaneously configured to receive.

Further, operating in the difference mode provides the surprising benefit of allowing a smaller spacing between the reflector and antenna than typically required without degrading the antenna impedance from 50 ohms, which in turn allows for a more compact design.

The antenna maybe a spiral antenna. Spiral antennas are considered to be frequency independent and can achieve bandwidths of 10:1 or more, and are capable of transmitting/receiving circularly polarised radiation which is beneficial for the RF decoy to detect radar signals.

Each of the first multi-arm planar antenna and second multi-arm planar antenna may comprise four arms and the RF feed system adapted to drive each antenna in a second order mode. In this arrangement the four arms may be divided into two pairs rotationally displaced from one another.

Spiral antennas normally need a balun transformer which enables radiation of a symmetric pattern well-matched to 50 ohms. However a four-arm spiral operated in the second mode utilises the symmetry of the two sets of spiral arms as a balun precluding the need for a separate balun allowing for a more compact antenna with simplified design and low cost that provides a radiation pattern suitable useful for RF decoys.

In one example, each antenna may comprise a dielectric support having a first side and a second side, the first and second sides facing opposing directions; the dielectric support carrying a first set of multiple conductive arms and a second set of multiple conductive arms; the first set of conductive arms arranged about the first side; each arm of the first set radiating away from a centre region, and substantially equally spaced apart circumferentially from one another about the centre region; the second set of conductive arms arranged about the second side; each arm of the second set radiating away from the centre region, and substantially equally spaced apart circumferentially from one another about the centre region; and in which the first set of arms are, as viewed from the first side, rotationally offset to the second set of arms such that each arm of the first set bisects an angle between adjacent arms of the second set.

The RF decoy may be an expendable RF decoy. The RF decoy may be configured to be launched from an aerial platform. The decoy maybe untethered to the aerial platform when broadcasting an RF decoy signal.

The invention will now be described by way of example with reference to the following figures in which:

Figure 1 is a perspective simplified schematic view of a RF decoy;

Figure 2 is a side view simplified schematic of the RF decoy illustrating simplified antenna patterns of the two antenna;

Figure 3 is a plan view of the planar antenna from a first side; and

Figure 4 a cross sectional view of a portion of the antenna of Fig 3 taken through line A-A to show connection with coaxial feed.

With reference to the Figures there is illustrated an active RF decoy 1, e.g. an expendable active decoy adapted to be deployed as an untethered decoy from an aerial platform. The RF decoy 1 comprises a casing 2 housing a first antenna 3; second antenna 4; a first RF reflector 5; a second RF reflector 6; a transceiver 7; a signal processor 8; two transmission lines 9 connecting each antenna 3,4 to the transceiver 7; and a battery 10.

The casing 2, which is elongate, has a first end 2A and second, opposite, end 2B. The casing 2 has dimensions allowing it to be housed within, and dispensed from, a standardised chaff or flare dispenser, e.g. as found commonly on certain aerial platforms.

The first antenna 3 and first RF reflector 5 are located at or towards the first end 2A of the casing 2, with the reflector 5 spaced inwardly from the antenna 3 by a distance optimised as a compromise between RF performance and compactness. The second antenna 4 and second RF reflector 6 are located at or towards the second end 2B of the casing 2 with the reflector 6 spaced inward from the antenna 4 by the same distance as reflector 5. Each antenna 3, 4 is connected to the transceiver 7 through a transmission line 9.

Each antenna 3,4 is a broadband antenna, e.g. adapted for operation over at least one octave. In the current embodiment each antenna 3,4 is a four-arm spiral antenna comprising two pairs of electrically conductive spiral arms. Each arm traces an Archimedean spiral path outwardly from an origin. The first pair of arms of each antenna are electrically connected at their inner ends to a first conductor 9A of the transmission line 9. The arms of the second pair are electrically connected at the central region of the spiral to a second conductor 9B of the transmission line 9, with a phase shift of 180 degrees relative to the first conductor. This allows the antenna to be operated in a difference mode as described later. In one embodiment each transmission line 9 is implemented by a coaxial cable.

The battery 10, is preferably a thermal battery. Its function is to power the transceiver 7 and signal processor 8 following the decoy's ejection from the dispenser of the platform.

Each antenna 3, 4 is orientated such that their nominal boresights are substantially collinear with one another and also collinear with a longitudinal axis X-X of the decoy 1. As such, the first antenna 4 is adapted to provide coverage across a first hemisphere extending away from the first end 2A, and the second antenna 6 adapted to provide coverage across a second hemisphere extending away from the second end 2B.

The first and second reflectors 5,6 act to increase gain of their respective antenna 3,4 in directions away from the other antenna, i.e. into the respective first and second hemispheres. The small depth of the reflectors was found to allow for efficient transmission of circular polarisation when driven in the difference mode, described below

When in use, whether transmitting or receiving, the transceiver 7 is adapted to operate both antennas 3,4 in a difference mode, also known as second order mode, in which the first pair of arms of each antenna 3,4 are fed in an inverted phase to the second pair of arms of each antenna 3,4. As seen in Fig 2, this produces a broader beam shape, compared with operation in a sum mode (i.e. with a main peak aligning with boresight, also referred to as first order mode), that includes two peaks spaced equally either side of antenna boresight.

In operation, and upon deployment of the decoy 1, the first and second antenna 3,4 may first be operated in receive mode to enable the processor 8 to scan for threats. If RF signals received through either antenna 3,4 match a perceived threat, the processor 8, selects and/or generates an appropriate waveform for transmission through both first and second antennas 3, 4 to lure, jam or otherwise deceive the threat.

Figures 3 and 4 illustrate an example design of planar spiral antenna 100 design suitable to implement each of antennas 3 and 4. The antenna 100 comprises a dielectric substrate 11 having a first side 11A and a second side 11B. The first and second sides 11A, 11B face away from one another in opposite directions. The dielectric substrate 11 may be comprised from any sheet material commonly used for providing the substrate layer of a printed circuit board. It may be rigid or flexible.

A first conductive pattern is carried on a first side 11 that defines, at least in part, two antenna elements or arms 14A 14B, and an annulus 15. A second conductive pattern is provided on the second side 11. The second conductive pattern provides a further two antenna elements or arms 17A 17B as well as a second central annulus 18. In Figure 3, which is a plan view of the antenna 100 facing the first side 11A, the electrically conductive pattern provided on the second side 11B is shown using dashed lines to illustrate the geometrical relationship between the features of the first and second patterns.

The conductive patterns may be provided on the substrate 11 using any suitable technique known to those skilled in the art, such as, for example, using a mask and etch process to pattern a metallised layer previously deposited on the substrate 11.

The central continuous annuli 15, 18 surround an aperture 19 that extends through the substrate 11 between the first side and second side 11A, 11B. The second central annulus 18 has a larger diameter than the first central annulus 15 of the first side 11A for reasons to be described below.

Each antenna element 14A, 14B 17A, 17B traces a spiral path that radiates outwardly from its respective central annulus 15, 18. In the present example the spirals are Archimedean spirals though, depending on the application, they may take other forms, such as logarithmic spirals and/or sinuous-spirals. The invention may also apply to non-spiral elements such as, for example, log periodic toothed elements.

The spiral elements 14A 14B of the first side are congruent and can be transposed through a 180 degree rotation about an axis Y-Y extending perpendicular to the faces of the first and second side through an origin point P lying within the aperture 19.

Similarly, the spiral elements 17A 17B of the second sides (shown in Fig 4 with the dashed lines) are congruent with one another, and can be transposed through an 180 degree rotation about the axis Y-Y

As seen in Fig 3, when viewed from the first side, the spiral elements14A 14B 17A 17B of the first and second sides all trace paths that travel in the same direction around the centre point as they radiate outwardly. From the vantage point of Fig 3, all arms trace an anti-clockwise path.

Further, to provide the greatest antenna efficiency, the pattern of spiral elements 14A 14B of the first side 11A is as near as possible congruent with the pattern of spiral elements 17A 17B of the second side but rotated by 90 degrees, such that each arm 14A 14B of the first side bisects the angle, in this case 180 degrees, between the arms 17A 17B of the second side. In practice, because of the different sizes of central annulus, congruency between the spirals of the first and second sides may be limited to outward portion of the spirals past the first quarter-turn from the central annulus.

With reference to Fig 4, the coaxial cable 30 comprises an inner (or core) electrical connector 31 and an outer electrical connector 32 that is coaxial with the inner connector 31.

The coaxial cable 30 approaches, and is connected to the antenna 100, from the second side 11B. The outer electrical connector 32 is directly bonded to the second annulus 18 on the second side 11B; the diameter of the second annulus being larger to have a diameter matching that of the annular outer electrical connector 32. The smaller inner electrical connector 31 extends through the aperture 19 and is bonded directly to the first central annulus 15.

Through this arrangement the spiral elements 14A 14B of the first side 11A are each electrically connected, and thus commonly fed, at their inner end to a first electrical conductor 31 of the transmission line 30, and similarly the spiral elements 17A 17B on the second side 11B are each electrically connected at their central end to the second electrical conductor 32 of the transmission line 30.

In a variant example decoy each antenna may comprise more than four arms. Where a single coaxial cable is used to feed each antenna, the antenna arms are still grouped into two sets driven at 180 degrees out of phase so that each antenna, depending on the number of arms, is driven in a third or higher order mode. Alternatively other mode radiation patterns can be achieved by the use of a standard multi-arm spiral where each arm feed has a phase progression of mode number x 360/number of arms. However, this latter arrangement requires a more complex and larger feed network and so is less suitable for this application.

In variant examples, the spiral may be logarithmic rather than Archimedean. The arms may trace sinuous spiral paths. Planar antenna are preferred as they are generally smaller though this is not essential.

The conductive arms of the antenna may take forms other than a spiral. For example, the arms may be sinuous and/or toothed log periodic. Generally, the form of the antenna is not essential so long as it can be driven in a second or higher order mode.

In an embodiment in which the decoy is only required to transmit but not receive, the transceiver may be substituted by a transmitter.

Claims

1. An RF decoy for protecting a platform from threats, the RF decoy having a first end and a second end;

the decoy comprising a first multi-arm planar antenna and a second multi-arm planar antenna, the first antenna located about the first end to radiate, when in use, nominally into a first hemisphere extending beyond the first end of the RF decoy and the second antenna located about the second end to radiate, when in use, in an opposite direction to the first antenna, nominally into a second hemisphere beyond the second end, and wherein the decoy comprises an RF feed system adapted to drive each antenna in a second order mode or higher order mode, such that the beam peak of each antenna is off-boresight.

2. An RF decoy according to claim 1 wherein the first multi-arm planar antenna and second multi-arm planar antenna each comprise spiral antenna arms.

3. A RF decoy according to claim 1 or 2 in which each of the first multi-arm planar antenna and second multi-arm planar antenna comprise four arms and the RF feed system is adapted to drive each antenna in a second order mode.