

Antenna System for Ultra-Wideband Radar Applications

Background

Technical Field

5 Embodiments of the invention relate generally to antenna systems suitable for ultra-wideband radar applications such as, but not limited to, ground penetrating radar systems and through wall radar systems.

Description of Related Art

10 In existing antenna systems, achieving impedance matching over a wide frequency range is particularly difficult and is often met with undesirable noise interferences and impedance-mismatch losses which cause oscillations.

 U.S. Patent No. 7,170,449 B2 (Eide) discloses an antenna system for ground penetrating radar, comprising at least two orthogonally mounted
15 transmitter antenna elements and at least two orthogonally mounted receiver antenna elements, in which the antenna elements consist of triangular monopoles formed by adding metal surfaces to a plate carrier, made of fiberglass substrate, that is mounted on the bottom side of a layer of radar absorbing material, wherein the upper side of the absorber is covered by a
20 metallic ground plane.

 Existing antenna systems and arrays are often plagued by problems such as omnidirectional electromagnetic leakages, interferences from adjacent antenna system, signal distortions in time domain and trailing oscillations, and therefore improved antenna system and antenna arrays are highly desired.

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Summary

Embodiments of the invention relate to antenna systems and antenna arrays which are suitable for ultra-wideband radar applications such as, but not limited to, ground penetrating radar systems and through wall penetration systems.

According to one embodiment of the invention, an antenna system comprises an internal antenna element having an antenna feed point, an antenna feed line and at least one impedance matching circuit wherein the at least one impedance matching circuit is at least partially enclosed by a magnetic material; a transceiver antenna provided at a first end of the internal antenna element and electrically coupled to the antenna feed point; and an electrically conductive reflector shield provided at the second end of the internal antenna element and electrically coupled to a second end of the internal antenna element, the reflector shield is arranged to at least partially surround the internal antenna element.

Multiple units of the antenna system may be juxtaposed to form an antenna array for increased area detection. Depending on detection requirements, the antenna array may be arranged with or without a gap between adjacent antenna systems.

Brief Description of the Drawings

Embodiments of the invention are disclosed hereinafter with reference to the drawings, in which:

Figure 1A illustrates a side cross-sectional view of an antenna system having an ellipsoidal-shaped reflector shield according to one embodiment of the invention;

Figure 1B illustrates an antenna array comprised of multiple units of the antenna system of Figure 1A;

Figure 1C illustrates another antenna array comprised of multiple units of the antenna system of Figure 1A;

Figure 1D illustrates yet another antenna array comprised of multiple units of the antenna system of Figure 1A;

Figure 2A illustrates a side cross-sectional view of an antenna system having a cuboid-shaped reflector shield according to another embodiment of the invention;

Figure 2B illustrates an antenna array comprised of multiple units of the antenna system of Figure 2A with a gap between adjacent units;

Figure 2C illustrates an antenna array comprised of multiple units of the antenna system of Figure 2A with no gap between adjacent units;

Figure 3A illustrates a side cross-sectional view of an antenna system having a trapezoidal-shaped reflector shield according to another embodiment of the invention;

Figure 3B illustrates an antenna array comprised of multiple units of the antenna system of Figure 3A with a gap between the reflector shields of adjacent units;

Figure 3C illustrates another antenna array comprised of multiple units of the antenna system of Figure 3A with no gap between the reflector shields of adjacent units;

Figure 4 illustrates a top through view of an antenna array comprised of multiple units of the antenna systems.

Detailed Description

In the following description, numerous specific details are set forth in order to provide a thorough understanding of various illustrative embodiments of the invention. It will be understood, however, to one skilled in the art, that embodiments of the invention may be practiced without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure pertinent aspects of embodiments being described. In the drawings, like reference numerals refer to same or similar functionalities or features throughout the several views.

Figure 1A illustrates a cross section of the antenna system 100 as viewed from the side according to one embodiment of the invention. In Figure

1A, the antenna system 100 includes an external reflector shield 10, an internal antenna element 20 at least partially surrounded by the reflector shield 10 and a transceiver antenna 30 provided on the internal antenna element 20.

5 The internal antenna element 20 may include an antenna feed point 22, an antenna feed line 24 and at least one impedance matching circuit 26, wherein the impedance matching circuit 26 is at least partially enclosed by a magnetic material. Examples of suitable magnetic materials include, but are not limited to, nickel zinc ferrite and manganese zinc ferrite. The magnetic
10 enclosure around the impedance matching circuit 26 may be provided by any of various methods. For example, the magnetic enclosure may be provided as a coating or plating. Alternatively, a magnetic enclosure may be provided as a casing or a housing which retains the impedance matching circuit 26 therein. The internal antenna element 20 may be provided in the form of a cylindrical
15 shape or other suitable shapes. In certain embodiments, two or more impedance circuits may be provided in an internal antenna element 20. In certain embodiments, the impedance matching circuit 26 may be substantially enclosed by a magnetic material. In certain embodiments, the antenna feed line 24 is also at least partially enclosed by a magnetic material. In certain
20 embodiments, the internal antenna element, other than the second end of the internal antenna element, is at least partially enclosed by another magnetic material.

 At a first end of the internal antenna element 20, a transceiver antenna
25 30 is electrically coupled to the antenna feed point 22. The transceiver antenna 30 is operable to transmit and receive radio signals as known in the art. At a second (opposed) end of the internal antenna element 20, the internal antenna element 20 is coupled to the reflector shield 10 and a coaxial cable 50. More particularly, the reflector shield 10 is electrically coupled to the antenna feed
30 point 22 via the antenna feed line 24. The coaxial cable 50 may have a characteristic impedance of fifty ohms. The centre conductor of the coaxial

cable 50 may be connected to the antenna feed line 24 and the screen of the coaxial cable 50 is connected to a ground plane.

5 The external reflector shield 10 is adapted to eliminate backward electromagnetic diffraction from the internal antenna element 20 and to reflect the same electromagnetic diffraction towards a desired forward direction. To this purpose, the reflector shield 10 is arranged to at least partially surround the internal antenna element 20.

10 The reflector shield 10 is electrically coupled to the antenna feed point through the antenna feed line and impedance matching circuit. The reflector shield 10 includes an electrically conductive material. Examples of suitable materials for the reflector shield 10 include metallic materials, e.g. copper and aluminium, and non-metallic electrically conductive materials. Further, the
15 reflector shield 10 may be provided in one of various forms, e.g. an opaque structure, a perforated structure, a lattice structure, a woven structure.

 In one embodiment (see Figure 1), the reflector shield 10 surrounds the length of the internal antenna element 20, leaving the transceiver antenna 30
20 unobstructed. In another embodiment (not shown), the reflector shield 10 and a radio-frequency (RF) absorber layer may be provided to fully enclose the internal antenna element 20. Examples of suitable materials for a RF absorbing layer include, but are not limited to, plastic and polyester.

25 The reflector shield 10 may be provided in any of various suitable shapes. Figure 1A illustrates a reflector shield 10 having an elliptical cross-sectional profile or ellipsoidal-shaped. A cavity or space between the reflector shield 10 and the internal antenna element 20 may be filled with air (which has a permittivity value of 1) or with other suitable materials. In certain other
30 embodiments, the enclosure may be filled with a material of higher permittivity, e.g. ceramic, so that the form factor of the antenna system 100 may be reduced.

It is to be appreciated that various forms of an ellipsoidal-shaped reflector shield 10 may be suitably employed. The dimensions of the semi-major and semi-minor axes of the ellipsoidal-shaped reflector shield 10 may be suitably varied as required in different embodiments. For example, the
5 ellipsoidal-shaped reflector shield 10 of Figures 1B and 1C have different semi-major and semi-minor axes dimensions. The ellipsoidal-shaped reflector shield of Figure 1D has equal semi-major and semi-minor axes dimensions.

In transmission operation, the feed point 22 of the internal antenna
10 element 20 receives a feed signal from the feed line 24 and transmits the feed signal forward through the transceiver antenna 30 to be radiated forward towards a desired destination. As electromagnetic radiation from the internal antenna element 20 is omnidirectional, backscattered electromagnetic radiation or signals from the internal antenna element 20 are reflected and directed
15 forward towards the desired destination. At the same time, the reflector shield 10 acts as a shield to prevent backscattered electromagnetic radiation from leaking backwards and/or in other directions covered by the reflector shield 10.

In other embodiments of the invention, the antenna system may be
20 provided with a reflector shield of other shapes, e.g. ellipse, half-sphere, cuboid, trapezoid, cone, pyramid, and parallelepiped. Figure 2A illustrates an antenna system 100a with a reflector shield 10a which is cuboid-shaped. Figure 3A illustrates an antenna system 100b with a reflector shield 10b which is trapezoidal-shaped. It is to be appreciated that the antenna systems 100a,
25 100b of Figures 2A to 4A also include components as described above in relation to the antenna system 100 of Figure 1A, wherein the components are arranged in similar configuration as in Figure 1A.

The antenna systems 100, 100a, 100b as described above and
30 illustrated in Figures 1A, 2A, 3A, may be employed singularly or, in certain applications, multiple antenna systems may be disposed as an antenna array (or phased array).

Figures 1B, 1C and 1D are examples of antenna arrays comprised of multiple antenna systems 100 with ellipsoidal-shaped reflector shields 10. The antenna array may be densely and closely packed with antenna systems 100 such that if one or more antenna system(s) 100 in the antenna array fails or malfunctions, other antenna systems 100 in the same array may provide replacement function by redundancy technology. However, it is to be appreciated that the number of antenna systems 100 in an antenna array may be determined by the application required.

Similarly, Figures 2B and 2C are examples of antenna arrays comprised of multiple antenna systems 100a with cuboid-shaped reflector shields 10a. In Figure 2C, the antenna systems 100a are juxtaposed to one another with no gap between adjacent antenna systems 100a. In Figure 2B, the antenna systems 100a are juxtaposed to one another with a gap 60 between reflector shields of adjacent antenna systems. The gap 60 may be dimensioned between zero millimetre to 1 metre. The gap dimension is ascertained according to the actual detection requirements, e.g. minimum resolution of hidden object size in the ground and burial depth of objects in the ground.

Similarly, Figures 3B and 3C are examples of antenna arrays comprised of multiple antenna systems 100b with trapezoidal-shaped reflector shields 10b. In Figures 3B and 3C, the antenna systems 100b are juxtaposed to one another with no gap between adjacent antenna systems 100b.

Similarly, Figure 4 shows a top through view of an antenna array comprised of multiple antenna systems 100c with half spherical-shaped reflector shield.

In order to meet changing requirements during operation, an antenna array of the present invention may adopt a variable gap which is adjustable depending on actual detection needs, e.g. special target detection, low sampling rate, quick large area scanning.

In certain embodiments of antenna arrays, the antenna systems may be arranged in a tabular structure of rows and columns such that the antenna systems are aligned to form a grid-like arrangement (e.g. Figures 1B to 1D, 4). In certain other embodiments of antenna arrays, the antenna systems may be disposed in a non-grid arrangement or in a random arrangement along three spatial dimensions (not shown).

Accordingly to another aspect of the invention, a construction method comprises: providing an internal antenna element having an antenna feed point, an antenna feed line and at least one impedance matching circuit wherein the at least one impedance matching circuit is at least partially enclosed by a magnetic material; disposing a transceiver antenna at a first end of the internal antenna element and electrically coupling the transceiver antenna to the antenna feed point; and coupling an electrically conductive reflector shield to a second end of the internal antenna element, the reflector shield being electrically coupled to the antenna feed point and arranged to at least partially surround the internal antenna element, wherein the inter-coupled internal antenna element, the transceiver antenna and the reflector shield form an antenna system.

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The method may include providing the magnetic material as at least one of nickel zinc ferrite and manganese zinc ferrite. The method may include disposing a ceramic material in a space between the reflector shield and the internal antenna element. The method may include providing the reflector shield having a shape selected from the group consisting of ellipse, half-sphere, cuboid, trapezoid, cone, pyramid and parallelepiped.

The method may further comprises juxtaposing a plurality of the antenna systems with a distance ranging between zero millimetre to 1 metre between the reflector shields of adjacent ones of the plurality of antenna systems to form an antenna array.

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Embodiments of the invention are particularly advantageous as described below:

- 5 • The provision of a magnetic enclosure around the impedance matching circuit(s), together with the arrangement of a reflector shield around the internal antenna element, eliminates electromagnetic radiation leakage in the antenna system of the present invention. This allows antenna systems to be arranged in array form with small or no gap between adjacent antenna systems without experiencing electromagnetic field interference from adjacent antenna systems. The antenna arrays in the present invention are capable of achieving excellent one-way radar signal transmission with fully shielded reflection over an ultra wideband frequency range. For example, in a ground penetrating radar (GPR) application, the immune performance for electromagnetic interference is excellent with insubstantial noise interference. Conventional ultra wide band radar systems presently adopt antenna array configurations with large gaps between adjacent antenna systems mainly due to radiation leakage that results in electromagnetic field interference to adjacent antenna systems.
- 10 • In operation, the effective radiation of an antenna array of the present invention may be directed at a desired direction. This may be achieved by employing phase control and intelligent network technologies to control the radio signals from each antenna system of the antenna array. Radio signal direction may be changed by electronic phase control instead of traditional mechanical rotating antenna surface and therefore the individual antenna system can achieve a wider detection angle displacement from vertical line without moving the antenna.
- 15 •
- 20 •
- 25 •

Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the invention. Furthermore, certain terminology has been used for the purposes of descriptive clarity, and not to limit the disclosed embodiments of the invention. The embodiments and features described above should be considered exemplary, with the invention being defined by the appended claims.

What is claimed is:

1. An antenna system comprising:
 - an internal antenna element having an antenna feed point, an antenna
 - 5 feed line and at least one impedance matching circuit wherein the at least one impedance matching circuit is at least partially enclosed by a magnetic material;
 - a transceiver antenna provided at a first end of the internal antenna element and electrically coupled to the antenna feed point; and
 - 10 an electrically conductive reflector shield provided at a second end of the internal antenna element and electrically coupled to the antenna feed line, the reflector shield is arranged to at least partially surround the internal antenna element.
- 15 2. The antenna system of claim 1, wherein the magnetic material includes at least one of nickel zinc ferrite and manganese zinc ferrite.
3. The antenna system of claim 1, wherein a space between the reflector shield and the internal antenna element is filled with air.
- 20 4. The antenna system of claim 1, wherein a space between the reflector shield and the internal antenna element is filled with a ceramic material.
5. The antenna system of claim 1, wherein the reflector shield has a shape
- 25 selected from the group consisting of ellipse, half-sphere, cuboid, trapezoid, cone, pyramid and parallelepiped.
6. The antenna system of claim 1, wherein the reflector shield includes a metallic material.
- 30 7. The antenna system of claim 1, wherein the reflector shield has a structure selected from the group consisting of an opaque structure, a perforated structure, a lattice structure and a woven structure.

8. The antenna system of claim 1, wherein the internal antenna element, other than the second end of the internal antenna element, is at least partially enclosed by another magnetic material.

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9. The antenna system of claim 1, wherein the at least one impedance matching circuit is substantially enclosed by a magnetic material.

10. The antenna system of claim 1, wherein the antenna feed line is at least partially enclosed by a magnetic material.

11. An antenna array comprising:
a plurality of the antenna systems of any of claims 1 to 10, wherein the plurality of the antenna systems are juxtaposed with a distance ranging between 0 millimetre to 1 metre between the reflector shields of adjacent ones of the plurality of antenna systems.

12. An antenna array comprising:
a plurality of the antenna systems of any of claims 1 to 10, wherein the plurality of the antenna systems are arranged in rows and columns.

13. An antenna array comprising:
a plurality of the antenna systems of any of claims 1 to 10, wherein the plurality of the antenna systems are arranged randomly along three spatial dimensions.

14. An antenna array comprising:
a plurality of the antenna systems of any of claims 1 to 10, wherein the plurality of the antenna systems are arranged randomly along three spatial dimensions with no gap between the reflector shields of adjacent ones of the plurality of the antenna systems.

15. A method comprising:

providing an internal antenna element having an antenna feed point, an antenna feed line and at least one impedance matching circuit wherein the at least one impedance matching circuit is at least partially enclosed by a magnetic material;

disposing a transceiver antenna at a first end of the internal antenna element, wherein the transceiver antenna is electrically coupled to the antenna feed point; and

coupling an electrically conductive reflector shield to a second end of the internal antenna element, the reflector shield being electrically coupled to the antenna feed point and arranged to at least partially surround the internal antenna element,

wherein the inter-coupled internal antenna element, the transceiver antenna and the reflector shield form an antenna system.

16. The method of claim 15, wherein the magnetic material includes at least one of nickel zinc ferrite and manganese zinc ferrite.

17. The method of claim 15, further comprising disposing a ceramic material in a space between the reflector shield and the internal antenna element.

18. The method of claim 15, wherein coupling an electrically conductive shield to a second end of the internal antenna element includes providing the reflector shield having a shape selected from the group consisting of ellipse, half-sphere, cuboid, trapezoid, cone, pyramid and parallelepiped.

19. The method of claim 15, further comprising juxtaposing a plurality of the antenna systems with a distance ranging between 0 millimetre to 1 metre between the reflector shields of adjacent ones of the plurality of antenna systems to form an antenna array.