

ANTENNA SHIELD

TECHNOLOGICAL FIELD

The presently disclosed subject matter relates to mechanical protection for antennas, in particular for phased array antennas.

BACKGROUND

The inventors consider that there are many applications of antennas in which mechanical protection thereof from threats that can potentially damage, destroy or render inoperable the antennas, is required or desirable.

One example of such an antenna, in which such mechanical protection is considered by the inventors to be desirable, includes a phased array antenna.

Conventionally, providing such mechanical protection in the form of a metal shield is counter intuitive and considered to be detrimental to the operation of the antenna, as the metal shield would be expected, conventionally, to block the transmission therethrough of the electromagnetic waves transmitted from and received by the antenna.

Polarizing filters for phased array antennas are known, and are commonly in the form of dielectric substrates (such as for example epoxy glass) with thin flat metal strips printed thereon. Such filters are sometimes placed forward of a phased array antenna, and such filters can be used for polarization of electromagnetic waves emitted by the antenna, or for rotating the plane of polarization of the antenna. The width of such metal strips is maintained below $1/20^{\text{th}}$, typically around $1/30^{\text{th}}$, of the wavelength of the electromagnetic energy transmitted by the antenna, and the depth of the strips (in a direction orthogonal to the plane of the dielectric substrate) is significantly less than this width. Accordingly, such polarizing filters are not considered to be able to provide mechanical protection for an antenna from a threat that can potentially damage, destroy or render inoperable the antenna.

Frequency Selective Surfaces (FSS) are known in the context of radar radomes, but are conventionally considered to be unsuitable at least for phased array antennas.

GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter there is provided a shield for an antenna, the shield comprising a plurality of rods, each rod at least having an external surface made from an electrical conducting material, the rods being in parallel spatial relationship one to another, the rods each having a respective curved transverse cross-section.

In at least some examples, the external surface covers a dielectric core, while in at least some other examples, the rods are made from the same or different electrical conducting materials.

For example, the shield is in the form of a parallelepiped, having a forward face and an aft face, the shield having a lateral length dimension, a height dimension, and a thickness dimension.

Additionally or alternatively, for example, in said parallel spatial relationship the rods are spaced from one another by respective gaps, wherein said inter rod gaps are empty. Alternatively, for example, in said parallel spatial relationship the rods are spaced from one another by respective gaps, and wherein said gaps are filled, partially or fully, with a suitable dielectric material.

Additionally or alternatively, for example, each said rod is elongate and extends rectilinearly along a respective longitudinal axis between a respective first longitudinal end and a respective second longitudinal end. For example, in said parallel relationship, the respective longitudinal axes of the rods are parallel to one another.

Additionally or alternatively, for example, each said curved transverse cross-section has a baseline height dimension. For example, each said curved transverse cross-section is circular, and wherein the baseline height dimension is a baseline diameter of the transverse cross-section. Alternatively, for example, each said curved transverse cross-section is egg-

shaped oval or elliptical, and wherein the baseline height dimension is a dimension of a respective minor axis of the respective egg-shaped oval or elliptical transverse cross-section.

Additionally or alternatively, for example, each said rod has a uniform said transverse cross-section along the length thereof.

Additionally or alternatively, for example, all the rods comprised in the shield have the same cross-sectional baseline height dimensions.

Additionally or alternatively, for example, an operating frequency of the antenna is 4.8 gigahertz, and the baseline height dimension is about 6mm (i.e., $6\text{mm} \pm 2\text{mm}$), or about 8 (i.e., $8\text{mm} \pm 2\text{mm}$), or in the range between about 6mm to about 8mm; alternatively, for example, an operating frequency of the antenna is 2.4 gigahertz, and the baseline height dimension is about 12mm (i.e., $12\text{mm} \pm 2\text{mm}$), or about 16mm (i.e., $16\text{mm} \pm 2\text{mm}$), or in the range between about 12mm to about 16mm.

Additionally or alternatively, for example, said rods are made from one or more materials and are so dimensioned and so shaped so as to together provide physical characteristics sufficient such as to provide mechanical protection to the antenna when the shield is interposed between the antenna and a source of an in-coming threat. For example, said physical characteristics include one or more of: mechanical strength, ductility, toughness, thickness, density, of the material.

Additionally or alternatively, for example, said rods are made from a mechanically resistant metal.

Additionally or alternatively, for example, said rods are made or comprise any one of or combination of steel, stainless steel, tungsten, chromium, titanium, iron.

Additionally or alternatively, for example, said baseline height dimension is significantly greater than $1/20^{\text{th}}$ of the respective operating minimum wavelength of the antenna.

Additionally or alternatively, for example, said baseline height dimension is less than or about $1/8^{\text{th}}$ or less than a respective operating minimum wavelength of the antenna, and wherein said baseline height dimension is greater than $1/20^{\text{th}}$ of the respective operating minimum wavelength of the antenna.

Additionally or alternatively, for example, the longitudinal axes of the respective said rods accommodated in the shield are fully included in planar aligned arrangement with respect to a single plane. For example, the single plane is orthogonal to a propagation direction of an electromagnetic beam transmitted and/or received by the antenna at zero azimuth and 0° elevation. Additionally or alternatively, for example, in said single plane an inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods is in the order of $1/4$ of the respective operating minimum wavelength of the antenna. For example, the inter-rod center spacing is about 30mm.

Additionally or alternatively, for example, the longitudinal axes of the respective said rods accommodated in the shield are divided into a number of groups, wherein in each said group the respective longitudinal axes are included in planar aligned arrangement with respect to a respective plane of a plurality of mutually parallel planes. For example, each said respective plane is orthogonal to a propagation direction of an electromagnetic beam transmitted and/or received by the antenna at zero azimuth and 0° elevation. Additionally or alternatively, for example, in said respective plane an inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods is in the order of $1/4$ of the respective operating minimum wavelength of the antenna. For example, the inter-rod center spacing is about 30mm. Additionally or alternatively, for example, each pair of adjacent said planes are spaced from one another by an inter-plane spacing, and wherein the inter-plane spacing is in the order of $1/4$ of the respective operating minimum wavelength of the antenna. For example, wherein the inter-plane spacing is about 30mm. Additionally or alternatively, for example, for each pair of adjacent said planes, the respective rods of one said adjacent plane are in staggered arrangement with respect to the respective rods of the other said adjacent plane. For example, in said staggered arrangement, each of the rods of one said adjacent plane are intercalated with respect to an adjacent pair of said rods of the other said adjacent plane. For example, in said staggered arrangement, each of the rods of one said adjacent plane are intercalated with respect to an adjacent pair of said rods of the other said adjacent plane by an intercalation spacing equal to half of the inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods. For example, in said staggered arrangement, each of the rods of one said adjacent plane are intercalated with respect to an adjacent pair of said rods of the other said adjacent plane by

an intercalation spacing less than half of the inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods.

Additionally or alternatively, for example, the shield comprises a frame structure configured for mechanically fixing the rods in said parallel spatial relationship one to another. For example, the frame structure includes a first frame member laterally spaced from a second frame member, each in orthogonal relationship with respect to the respective longitudinal axes of the rods, and wherein the rods are mechanically fixed to the first frame member via the respective first longitudinal ends of the rods, and wherein the rods are mechanically fixed to the second frame member via the respective second longitudinal ends of the rods. For example, the frame structure further comprises a top frame member and a bottom frame member, each joined at respective lateral ends thereof to the first frame member and the second frame member. For example, the frame structure comprises one or more thin cross-sectioned intermediate vertical members, each said thin cross-sectioned intermediate vertical member linking the top frame member and the bottom frame member to one another. Additionally or alternatively, for example, the frame structure is made from any suitable dielectric material or from a metal. Additionally or alternatively, for example, the rods are mounted to the frame via a first shock absorber arrangement.

Additionally, or alternatively, for example, the shield comprises one or more dielectric sheets, in nominally parallel relationship with respect to a forward face of the shield, the one or more dielectric sheets being configured for providing a level of protection to the antenna. For example, the shield comprises at least one of the following: one said dielectric sheet affixed to the forward face; one said dielectric sheet fixed to an aft face of the shield; at least one said dielectric sheet fixed within the shield.

Additionally, or alternatively, for example, the shield comprises a foam material filling spaces between the rods.

According to a second aspect of the presently disclosed subject matter, there is provided an antenna installation, comprising:

- an antenna having a forward antenna face for emitting and/or receiving electromagnetic radiation;
- a shield as defined herein regarding the first aspect of the presently disclosed subject matter, spaced forward of said forward antenna face by a forward spacing.

For example, the shield is operative for providing protection to the antenna for threats originating in a direction towards the forward antenna face, wherein said direction is included within a channel defined by a respective maximum azimuth range and an elevation range of the antenna.

For example, the respective maximum azimuth range is $\pm 60^\circ$, and the respective maximum elevation of the antenna is $\pm 60^\circ$.

Additionally or alternatively, for example, the channel diverges and increases a cross-sectional area thereof in a direction away from the forward antenna face, in particular in a forward direction away from the forward antenna face.

Additionally or alternatively, for example, a height dimension of the shield and the length dimension of the shield are such as to ensure that the respective rods fully traverse a length and a height of a cross-section of the channel corresponding to a location of the shield in the channel.

Additionally or alternatively, for example, the channel is defined by a top surface, a bottom surface, a right side surface and a left side surface, wherein a height dimension of the shield is such that the top surface of the channel intersects an uppermost said rod of the shield, and such that the bottom surface of the channel is any one close to abutting, or intersecting, a lowermost said rod of the shield, and wherein a length dimension of the shield is such that the right side surface and the left side surface of the channel each intersect all of the rods of the shield.

Additionally or alternatively, for example, the antenna installation includes a protection structure configured for providing at least protection from a threat having a trajectory towards the antenna that avoids crossing into the channel and that is towards the antenna. For example, wherein the protection structure comprises a peripheral wall and a top wall. Additionally or alternatively, for example, the antenna installation comprises a second shock absorber arrangement interconnecting the shield to the protection structure.

Additionally or alternatively, for example, the antenna is any one of:

- a static phased array antenna;
- a static radio antenna or a static TV antenna;

- a revolving antenna, in which the shield is mechanically coupled to the antenna, and wherein the shield and the antenna revolve as a unit about the rotation axis of the antenna.

Additionally or alternatively, for example, the antenna is any one of: a passive electronic scanned array (PESA); an active electronically scanned array (AESA); a hybrid beam forming phased array; a digital beam forming (DBF) array; or a conformal antenna in which individual antennas are arranged on a curved surface, and phase shifters operate to enable the conformal antenna to generate a plane wave.

Additionally or alternatively, for example, the antenna is operative to generate a steerable radio beam having a propagation direction, the radio beam having an oscillating electric field along an electric field plane, and wherein said longitudinal axes of the respective rods are non-parallel with respect to the electric field plane.

Additionally or alternatively, for example, said radio beam is operable at a radio frequency range in any one or more of the X-band, S-band, C-band, or L-band.

According to a second aspect of the presently disclosed subject matter, there is provided a method for protecting an antenna, the antenna having a forward antenna face for emitting and/or receiving electromagnetic radiation, the method comprising:

- providing a shield as defined herein regarding the first aspect of the presently disclosed subject matter;
- spacing the shield forward of said forward face.

A feature of at least one example of the presently disclosed subject matter is that a shield is provided for enabling an antenna to be mechanically protected at least from a threat, for example a threat that can potentially damage, destroy or render inoperable the antenna.

Another feature of at least one example of the presently disclosed subject matter is that a shield is provided for enabling an antenna to be mechanically protected.

Another feature of at least one example of the presently disclosed subject matter is that a shield is provided, particular for use with a phased array antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it can be carried out in practice, examples will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1A is a side view of a static antenna according to an aspect of the presently disclosed subject matter; **Fig. 1B** is a top view of the antenna example of Fig. 1A.

Fig. 2 is an isometric view of a shield according to a first example of the presently disclosed subject matter; **Fig. 2A** is a front view of an example of a rod comprised in the shield example of Fig. 2; **Fig. 2B** is a cross-sectional view of the rod example of Fig. 2A taken along A-A.

Fig. 3A is a top view of an example of an antenna installation, including the antenna example of Figs. 1A, 1B, and the shield example of Figs. 2, 2A, 2B; **Fig. 3B** is a cross-sectional side view of the example of Fig. 3A, taken along B-B; **Fig. 3C** is an isometric view of the example of Fig. 3A.

Fig. 4 is an isometric view of the shield example of Figs. 2, 2A, 2B.

Fig. 5 is a cross-sectional side view of an example of a rod arrangement for the shield example of Figs. 2, 2A, 2B.

Fig. 6 is a cross-sectional side view of another example of a rod arrangement for the shield example of Figs. 2, 2A, 2B.

Fig. 7 is a cross-sectional side view of another example of a rod arrangement for the shield example of Figs. 2, 2A, 2B.

Fig. 8 is a cross-sectional side view of another example of a rod arrangement for the shield example of Figs. 2, 2A, 2B.

Fig. 9 is a cross-sectional side view of another example of a rod arrangement for the shield example of Figs. 2, 2A, 2B.

Fig. 10 is a cross-sectional side view of another example of a rod arrangement for the shield example of Figs. 2, 2A, 2B.

DETAILED DESCRIPTION

According to a first aspect of the presently disclosed subject matter, and referring to Fig. 2, a shield (also referred to herein interchangeably as a mechanical shield or as an antenna shield) according to a first example, generally designated with reference numeral **10**, comprises a plurality of rods **30**, the rods **30** being in parallel spatial relationship one to another.

In at least one example, and referring also to Figs. 1A and 1B, the shield **10** is for use with an antenna **100** that operates to transmit and/or receive electromagnetic energy. Furthermore, while in at least this example, the antenna **100** is a static phased array antenna, in at least some other examples, the respective antenna can be any other suitable antenna, for example a static antenna, for example a static radio antenna or static TV antenna. In yet other examples, the respective antenna can be any other suitable antenna, for example a revolving antenna, in which the shield is coupled to, and revolves with, the antenna.

For example, the antenna **100** can be any one of: a passive electronically scanned array (PESA); or an active electronically scanned array (AESA); or a hybrid beam forming phased array; or a digital beam forming (DBF) array; or a conformal antenna in which individual antennas are arranged on a curved surface, and phase shifters operate to enable the conformal antenna to generate a plane wave. In yet other examples the antenna can be a non-phased array antenna, for example.

In at least this example, the antenna **100** comprises a plurality of antenna elements (not shown) within an antenna envelope **AE** and which operate in a conventional manner to generate at least one beam **RB** of electromagnetic energy in the form of radio waves in a forward direction with respect to the antenna **100**, and to steer the beam **RB** in azimuth and elevation. For example, the azimuth and elevation can be defined with respect to a global angular coordinate system, in which elevation angle is defined relative to the horizon, while azimuth angle is orthogonal to the elevation angle but also defined relative to the horizon. For example, the antenna **100** can be operated to steer the beam **RB** in azimuth and elevation within a respective maximum azimuth range $\pm\phi$ and a respective maximum positive elevation θ (i.e., a respective elevation range from 0° (nominally horizontal, parallel to the horizon) to the maximum positive elevation θ above the horizon) or within a respective

maximum elevation range $\pm\theta$ (i.e., a respective elevation range spanning between above and below the horizon).

For example, such an antenna envelope **AE** comprises a forward face **FF**, through which the radio beam **RB** exits the antenna **100** and into which reflected radio beams are received by the antenna **100**.

In at least this example, the antenna envelope **AE** is generally orthogonal to a horizontal plane **HP**, such as for example the ground, and the forward face **FF** is thus orthogonal to the horizontal plane **HP**.

However, in at least some alternative variations of this example, the antenna envelope **AE**, and thus the forward face **FF**, can be inclined at a desired inclination angle α with respect to the horizontal plane **HP**, as shown by the dotted line in Fig. 1A for example.

The radio beam **RB** has a propagation direction **V**, which in operation of the antenna **100** can be steered in azimuth and elevation as disclosed above, the propagation direction being generally rectilinear.

The radio beam **RB**, which is typically a polarized beam of electromagnetic energy, has an oscillating electric field **E** along a first plane **P1**, and a perpendicular oscillating magnetic field **B** along a second plane **P2**, wherein the first plane **P1** is perpendicular with respect to the second plane **P2**.

In at least this example, the first plane **P1** is vertical, and thus also orthogonal to the horizontal plane **HP**. The orientation of the first plane **P1** on the horizontal plane **HP** varies with the azimuth angle of the radio beam **RB**. The second plane **P2** is at an angle with respect to the horizontal plane **HP** that varies according to the elevation angle of the radio beam **RB**.

In at least various implementations of at least this example, the respective antenna **100** can operate in a suitable radio frequency (or radio frequency range) and corresponding operating wavelength λ (or corresponding wavelength range **R λ**). While such a radio frequency (or corresponding frequency range) can be in any one or more of: the L-band (frequency range 1GHz to 2GHz), S-band (frequency range 2GHz to 4GHz), C-band (frequency range 4GHz to 8GHz), X-band (frequency range 8GHz to 12GHz), UHF band, or VHF band, the following examples will be based on operation of the antenna **100** in the S-band.

Referring again to Fig. 2, the shield **10** comprises a frame structure **20** that is configured for mechanically fixing the rods **30** in said parallel spatial relationship one to another. In said parallel spatial relationship the rods **30** are spaced from one another by respective gaps **IRG** providing corresponding inter-rod spacings **IRS**. The inter rod gaps **IRG** can be empty (i.e., is open to the atmospheric environment) or can be filled, partially or fully, with a suitable dielectric material, for example.

In at least this example, the shield **10** (and in at least this example, also the frame structure **20**) is in the form of a parallelepiped, having a rectangular forward face **SFF** and a rectangular aft face **SAF**, each having a lateral length dimension **LD** and a height dimension **HD**, and separated by a thickness dimension **TD**.

Referring also to Fig. 2A, each rod **30** is elongate, having a longitudinal length **L**, and extends rectilinearly along a respective longitudinal axis **LA** between a respective first longitudinal end **32** and a respective second longitudinal end **34**. In said parallel relationship, the respective longitudinal axes **LA** of the rods **30** are parallel to one another.

In at least some examples, the longitudinal length **L** is about 2200mm, in other examples, the longitudinal length **L** can be 7m to 9m.

In general, the length **L** is a predetermined length greater than the width of the antenna **100**.

Referring in particular to Fig. 2B, each rod **30** also has a curved transverse cross-section **CC**. In at least this example, each respective cross-section **CC** of the plurality of rods **30** in the shield **10** is circular. However, other suitable curved cross sections are also possible. For example, in at least some alternative variations of this example, the curved cross-section **CC** can instead be similar to an egg-shaped oval, or can be elliptical, for example. In the case of an egg-shaped oval cross section, the major axis thereof (corresponding to the axis of symmetry of the cross section) is aligned with or parallel to the propagation direction **V** at least at one elevation angle of the radio beam **RB**, for example at 0° elevation angle (i.e., horizontal). Similarly, in the case of an elliptical cross section, the major axis of the cross section is aligned with or parallel to the propagation direction **V** at least at one elevation angle of the radio beam **RB**, for example at 0° elevation angle (i.e., horizontal).

In at least this example, each rod has a uniform cross section along the length thereof, and all the rods **30** have the same cross-sectional size, for example the same diameter, referred to herein as a baseline cross-sectional height; in this example, in which the rods have a circular cross-section, the baseline cross-sectional height is in the form of a baseline diameter **D**. However, in at least some alternative variations of this example, the respective rods can have different diameters (or different sized minor axes of the respective cross sections, in cases where the respective cross-sections **CC** are egg-shaped oval or elliptical) one from the other, within a range, and in which the maximum diameter (or respective minor axis) of the rods in such a range is of a size corresponding to the above mentioned baseline height dimension, or baseline diameter **D**.

In at least some examples, the baseline height dimension, or baseline diameter **D**, is about 12mm. In at least one example, the operating frequency λ is 2.4 gigahertz, and the baseline height dimension is about 12mm or 16mm, or in the range 12mm to 16mm.

In at least some other examples, the baseline height dimension, or baseline diameter **D**, is about 6mm. In at least one example, the operating frequency λ is 4.8 gigahertz, and the baseline height dimension is about 6mm or about 8mm, or in the range 6mm to 8mm.

The longitudinal length **L** of each rod **30** is much greater than the respective baseline height dimension or baseline diameter **D** thereof. For example, the ratio **L/D** of the longitudinal length **L** to the respective baseline height dimension or baseline diameter **D** is greater than **10**, for example 600 to 900.

In at least this example, the rods **30** are made from one or more materials **M** and are so dimensioned and so shaped so as to together provide physical characteristics, in particular mechanical characteristics, such as to provide protection to the antenna **100** when the shield **10** is interposed between the antenna **100** and the source of an approaching threat (Figs. 3A, 3B).

According to an aspect of the presently disclosed subject matter, each rod **30** has an external surface **35** made from an electrical conducting material **ME** such as for example a metal.

In at least some examples, such one or more materials **M** includes a dielectric core, coated or otherwise surrounded by an external layer of an electrical conducting material **ME**,

such as for example a metal. The dielectric core materials and the electrical conducting material are chosen such that, when so-shaped and so-dimensioned according to the presently disclosed subject matter, the rod has physical characteristics, in particular mechanical strength, that are sufficient to provide protection to the antenna **100** when the shield **10** is interposed between the antenna **100** and the source of an in-coming threat.

In other examples, such one or more materials **M** includes an electrical conducting material **ME**, such as for example a metal, chosen such that, when so-shaped and so-dimensioned according to the presently disclosed subject matter, it has physical characteristics, in particular mechanical strength, that are sufficient to provide suitable mechanical protection to the antenna **100** when the shield **10** is interposed between the antenna **100** and the source of an in-coming threat.

Such physical characteristics, in particular such mechanical characteristics, can include one or more of mechanical strength, ductility, toughness, thickness (corresponding to the respective baseline height dimension or baseline diameter **D**), density, and so on, of the material **M** or of electrical conducting material **ME**, which contribute to enable the rods **30** made from the material **M** (and optimally of electrical conducting material **ME**) to provide high resistance-to-impact damage, and thus an ability to withstand the impact of such a threat, or to mitigate the damage effects on the antenna **100** of such an impact.

Thus, such physical characteristics also include electrical conductivity on at least the outer facing surface **35** of the respective rods **30**.

By threat is meant herein to include inter alia a plurality of elements, for example low-mass, high velocity elements, wherein for example each such element has a characteristic dimension, for example diameter, for example in the range of several millimeters to several centimeters, for example up to about 5cm and that such a plurality of on-coming elements, in the absence of the shield, would be expected to cause damage to the respective antenna to a degree at least sufficient to impair or prevent operation of the antenna, or to a degree that could destroy the antenna. For example, such elements can include bullets from small arms to heavy machine guns, or vehicles that are directly guided to the antenna, or the like.

By "protection" (also interchangeably referred to herein as "mechanical protection") is meant that the rods **30** are configured for stopping such elements when impacting onto

the rods **30**, and/or deflecting such elements when impacting onto the rods **30**, and/or for absorbing sufficient impact energy when impacting onto the rods **30**, such as to avoid mechanically damaging the antenna **100**, or at least such as to minimize damaging the antenna **100**, such that the antenna is able to function to transmit and/or receive electromagnetic waves, and/or, such that the antenna **100** can be easily and quickly repaired in-situ.

According to an aspect of the presently disclosed subject matter, the respective baseline height dimension or baseline diameter **D** is significantly greater than $1/20^{\text{th}}$ of the respective operating wavelength λ (i.e., $\mathbf{D} \gg 0.05 * \lambda$) of the antenna **100**. In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range $\mathbf{R}\lambda$, the respective baseline height dimension or baseline diameter **D** is significantly greater than $1/20^{\text{th}}$ of minimum wavelength λ_{MIN} of the respective operating wavelength range $\mathbf{R}\lambda$ (i.e., $\mathbf{D} \gg 0.05 * \lambda_{\text{MIN}}$).

According to this aspect of the presently disclosed subject matter, the respective baseline height dimension or baseline diameter **D** is as large as possible to provide maximum mechanical strength to the respective rod **30**, and thus maximize protection provided by the rod **30**, and at the same time the respective baseline height dimension or baseline diameter **D** is about $1/8^{\text{th}}$ or less of the respective operating wavelength λ (i.e., $\mathbf{D} \leq 0.125 * \lambda$), but still significantly greater than $1/20^{\text{th}}$ of the respective operating wavelength λ ($0.050 * \lambda < \mathbf{D} \leq 0.125 * \lambda$). In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range $\mathbf{R}\lambda$, the respective baseline height dimension or baseline diameter **D** is as large as possible to provide maximum mechanical strength to the respective rod **30**, and thus maximize protection provided by the rod **30**, and at the same time the respective baseline height dimension or baseline diameter **D** is about $1/8^{\text{th}}$ or less of the respective minimum wavelength λ_{MIN} of the respective operating wavelength range $\mathbf{R}\lambda$ (i.e., $\mathbf{D} \leq 0.125 * \lambda_{\text{MIN}}$), but still significantly greater than $1/20^{\text{th}}$ of the respective minimum wavelength λ_{MIN} of the respective operating wavelength range $\mathbf{R}\lambda$ ($0.050 * \lambda_{\text{MIN}} < \mathbf{D} \leq 0.125 * \lambda_{\text{MIN}}$).

In yet other examples, the respective baseline height dimension or baseline diameter **D** can exceed about $1/8^{\text{th}}$, for example up to about $1/4$ of the respective wavelength λ or of the respective minimum wavelength λ_{MIN} ; however, and without being bound to theory,

inventors consider that there can be a degradation of the signal of the beam, and some of the electromagnetic energy transmitted and/or received via the shield can be reflected by the shield.

According to this aspect of the presently disclosed subject matter, the respective baseline height dimension or baseline diameter **D** is as large as possible to provide maximum mechanical strength to the respective rod **30**, and thus maximize protection provided by the rod **30**, and at the same time the respective baseline height dimension or baseline diameter **D** is a proportion **N**, or less than proportion **N**, of the respective operating wavelength λ , wherein the proportion **N** is greater than 0.05 and also less than or equal to any one of the following values: 0.12; 0.11, 0.10; 0.09; 0.08; 0.07; 0.06. In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range $R\lambda$, the respective baseline height dimension or baseline diameter **D** is as large as possible to provide maximum mechanical strength to the respective rod **30**, and thus maximize protection provided by the rod **30**, and at the same time the respective baseline height dimension or baseline diameter **D** is a proportion **N**, or less than proportion **N**, of the respective minimum wavelength λ_{MIN} of the respective operating wavelength range $R\lambda$, wherein the proportion **N** is greater than 0.05 and also less than or equal to any one of the following values, or any other value between the following values: 0.12; 0.11, 0.10; 0.09; 0.08; 0.07; 0.06.

According to this aspect of the presently disclosed subject matter, the respective baseline height dimension or baseline diameter **D** is as large as possible to provide maximum mechanical strength to the respective rod **30**, and thus maximize protection provided by the rod **30**, and at the same time the respective baseline height dimension or baseline diameter **D** is a proportion **N**, or less than proportion **N**, of the respective operating wavelength λ , wherein the proportion **N** is included in any one of the following ranges of values: 0.12 to 0.05; 0.11 to 0.05; 0.10 to 0.05, 0.09 to 0.05; 0.08 to 0.05; 0.07 to 0.05; 0.06 to 0.05. In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range $R\lambda$, the respective baseline height dimension or baseline diameter **D** is as large as possible to provide maximum mechanical strength to the respective rod **30**, and thus maximize protection provided by the rod **30**, and at the same time the respective baseline height dimension or baseline diameter **D** is a proportion **N**, or less than proportion **N**, of the respective minimum wavelength λ_{MIN} of the respective operating

wavelength range $R\lambda$, wherein the proportion N is included in at least one of the following ranges of values: 0.12 to 0.05; 0.11 to 0.05; 0.10 to 0.05, 0.09 to 0.05; 0.08 to 0.05; 0.07 to 0.05; 0.06 to 0.05.

In at least this example, rods **30** including the outer surfaces **35** thereof are made from a resistant metal, for example any one of or combination of steel, stainless steel, tungsten, chromium, titanium, iron.

Referring to Fig. 3A, Fig. 3B and Fig. 3C, an antenna installation **210** includes a shield **10** and an antenna **100** spaced therefrom by spacing **SX**. In at least some examples, the spacing **SX** is about 500mm, while in other examples the spacing **SX** can be much higher.

It is to be noted that the shield **10** is configured for providing protection to the antenna **100** for threats originating in a direction towards the forward face **FF** of the antenna **100**, in particular, in such a direction included within a channel **CH** defined by the respective maximum azimuth range $\pm\phi$ and the respective maximum positive elevation θ of the antenna **100** (i.e., and the respective elevation range from 0° (nominally horizontal) to the maximum positive elevation θ).

The channel **CH** is thus generally defined by the scan volume of the antenna, i.e., the maximum azimuth range and maximum elevation range that can be provided by the antenna.

The channel **CH** can thus be defined by any suitable combination of maximum azimuth range and maximum elevation.

In at least some examples, the respective maximum azimuth range is $\pm 30^\circ$, and the respective maximum elevation of the antenna **100** is $+40^\circ$. In yet at least some other examples, the respective maximum azimuth range is $\pm 60^\circ$, and the respective maximum elevation of the antenna **100** is $\pm 60^\circ$.

The channel **CH** thus diverges and increases its cross-sectional area in a direction away from the forward face **FF** of the antenna **100**.

Thus, for example, the channel **CH** can be defined by four imaginary surfaces as follows:

- a top surface **ST**, projecting forward and upward of the front face **CC** at the top edge **TE** thereof at an elevation angle equal to the maximum positive elevation θ of the antenna **100**;
- a bottom surface **SB**, defined by the horizontal plane **HP**, corresponding to a respective elevation of 0° ;
- a right side surface **SSR** on the right hand side of the antenna envelope **AE**, projecting forward and to the right of the front face **CC** at the right edge **RE** thereof at an azimuth angle equal to the maximum positive azimuth $+\phi$ of the antenna **100**;
- a left side surface **SSL** on the left hand side of the antenna envelope **AE**, projecting forward and to the left of the front face **CC** at the left edge **LE** thereof at an azimuth angle equal to the maximum negative azimuth $-\phi$ of the antenna **100**.

In at least some alternative variations of this example, and in which the lower edge **LE** of the front face **FF** is elevated from the horizontal plane **HP**, such that the beam **RB** can be steered to a negative elevation angle, the respective bottom surface **SB** is instead projecting forward and downward of the front face **CC** at the bottom edge **BE** thereof at an elevation angle equal to the maximum elevation θ (less than 0°) of the antenna **100**. Such cases can include, for example, where the antenna is located on top of a building, hill or mountain in which a look-down capability is required or desired. In at least some such examples, the respective maximum azimuth range is $\pm 30^\circ$, and the respective maximum elevation of the antenna **100** is $\pm 40^\circ$. In yet at least some other examples, the respective maximum azimuth range is $\pm 60^\circ$, and the respective maximum elevation range of the antenna **100** is $\pm 60^\circ$.

The antenna **10** is positioned forward of the forward face **FF** of the antenna **100**, by a forward spacing **SX**.

Furthermore in at least this example, the antenna installation **210** includes any suitable protection structure **200** configured for providing protection, for the sides, back and top of the antenna **100**, and coming from other directions not included within the channel **CH**. In other words, the protection structure **200** is configured for providing mechanical protection from threats having a trajectory towards the antenna **100** that does not cross into

the channel **CH** and is nevertheless towards the antenna **10**. For example, the protection structure **200** can be in the form of a bunker or hardened shell, having a peripheral wall **220** and top wall **240**. For example, the protection structure **200** can be made from reinforced concrete, stone, steel plates, and so on.

In at least some alternative variations of this example, the protection structure can instead be in the form of a cave, or other natural formation such as an overhang, or for example a number of man-made static or mobile structures arranged around the aft and sides of the antenna, outside the channel **CH**.

In at least some alternative variations of this example, the protection structure can be omitted. This can be the case, for example, where no threat is considered to be able to originate from outside the channel **CH**, or where the risk of such a threat is considered minimal, or where there is insufficient time to provide such a protection structure prior to operating the antenna.

The minimum size of the shield **10**, in particular the frame **20**, generally depends on the magnitude of the forward spacing **SX**, as well as on the scan volume of the antenna defined by the channel **CH**.

For a given channel **CH**, the greater the forward spacing **SX**, the greater the length dimension **LD** and the height dimension **HD** need to be, in proportion to the respective maximum positive elevation θ or in proportion to the respective maximum positive azimuth $+\phi$ or respective maximum negative azimuth $-\phi$, respectively. Conversely, the smaller the forward spacing **SX**, the smaller the length dimension **LD** and the height dimension **HD** need to be, in proportion to the respective maximum positive elevation θ or in proportion to the respective maximum positive azimuth $+\phi$ or respective maximum negative azimuth $-\phi$, respectively.

In such cases, the peripheral dimension of the peripheral wall **220** can be such as to provide a forward opening **250**, and such that the peripheral wall **220** is as close to, but without traversing into, the channel **CH**, in particular the right side surface **SSR** or left side surface **SSL** thereof. The height dimension of the peripheral wall **220**, and the forward extent of the top wall **240** are such that the peripheral wall **220** and the top wall are each as close to, but without traversing into, the channel **CH**, in particular the top surface **ST** thereof.

Thus, a relatively smaller forward spacing **SX** can enable the dimensions of the protection structure **200** to be relatively small, while a relatively larger forward spacing **SX** can require the dimensions of the protection structure **200** to be relatively larger.

A relatively smaller forward spacing **SX** can be advantageous inasmuch as the length dimension **LD** and the height dimension **HD** can be small, which in turn can result in a cheaper and lighter shield **10**. Conversely, a relatively larger forward spacing **SX** can be expected to minimize potential damage to the antenna of any element that still manages to traverse the thickness of the shield and continues to travel towards the antenna **100**, albeit with diminished momentum and diminished kinetic energy.

Thus, the magnitude of the forward spacing **SX** can be optimized for each application of the presently disclosed subject matter, according to the nature of the perceived threat, transport access and available area at the installation site, among other considerations.

For example, if for a particular application it is expected that there is a relatively small risk of a threat, and/or a relatively low risk of high occurrences of threats, the forward spacing **SX** can be relatively small, allowing the dimensions of the shield **10**, in particular of the frame **20**, to be relatively small. Furthermore, if the installation area around which the antenna **100** is positioned is small, and/or if transport access to the installation area is difficult or impossible for large items, then a smaller-sized frame **20** could be more optimal, and thus the forward spacing **SX** can be correspondingly relatively smaller.

Conversely, for example, if for a particular application it is expected that there is a relatively large risk of a threat, the forward spacing **SX** can be relatively large, necessitating the dimensions of the shield **10**, in particular of the frame **20**, to be relatively large. Furthermore, if the installation area around which the antenna **100** is positioned is relatively large, and/or if transport access to the installation area is not unduly difficult for large items, then a relatively larger-sized frame **20** could be more optimal, and thus the forward spacing **SX** can be correspondingly larger.

As disclosed above, the radio beam **RB**, which is typically a polarized beam of electromagnetic energy, has an oscillating electric field **E** along a first plane **P1**, which, in at least this example, is vertical. In other words, and at least in this example, the radio beam **BM** is a nominally vertically polarized beam.

In any case, and as will become clearer herein, and the rods **30** are longitudinally aligned in orthogonal relationship to the nominal polarization at the boresight position (zero azimuth, zero elevation). In other words, the longitudinal axes of the rods are orthogonal to the polarization of the radio beam **RB**: for example, if the radio beam **RB** is horizontally polarized, the rods **30** are aligned with the respective longitudinal axes vertical; for example, if the radio beam **RB** is vertically polarized, the rods **30** are aligned with the respective longitudinal axes horizontal; for example, if the radio beam **RB** is diagonally polarized (+45°), the rods **30** are aligned with the respective longitudinal axes diagonally disposed in the orthogonal direction (-45°).

According to an aspect of the presently disclosed subject matter, the rods **30** are positioned in the shield **10** with respect to the antenna **100** (at the aforesaid forward spacing **SX**) such that the longitudinal axes **LA** of the respective rods **30** are not parallel with respect to the first plane **P1**. In at least this example the longitudinal axes **LA** of the respective rods **30** are oriented orthogonally with respect to the first plane **P1** when the beam **RB** is at zero azimuth. Concurrently the longitudinal axes **LA** of the respective rods **30** are parallel with respect to the second plane **P2** when the beam **RB** is at an elevation of 0°.

Thus, in at least this example, the plurality of rods **30** of the shield **10**, when the shield **10** is installed forward of the antenna **100**, are oriented such that the respective longitudinal axes **LA** are parallel to the horizontal plane **HP**, for example as illustrated in Fig. 3B.

Without being bound to theory, inventors consider that having all the rods **30** oriented parallel to the first plane **P1** can result in the electromagnetic waves of the beam **RB** "short circuiting" (causing the beam to be reflected back towards the source), and thus can prevent passage of the beam **RB** through the shield **10**.

Referring to Fig. 4, the longitudinal axes **LA** of the plurality of rods **30** accommodated in the shield **10** can be fully included in planar aligned arrangement with respect to a single third plane **P3**, or can be divided into a number of groups wherein in each group the respective longitudinal axes **LA** are included in planar aligned arrangement with respect to a respective third plane **P3** of a plurality of mutually parallel third planes **P3**. The one or more respective third planes **P3** is/are orthogonal to the first plane **P1**. In at least this

example, the one or more respective third planes **P3** is/are orthogonal to the horizontal plane **HP**.

In at least this example, the frame **20** includes a left frame member **22** and a right frame member **24**, laterally spaced from one another and in orthogonal relationship with respect to the respective longitudinal axes **LA**. The plurality of rods **30** are mechanically fixed to the left frame member **22** via the respective first longitudinal ends **32**, and the plurality of rods **30** are mechanically fixed to the right frame member **24** via the respective second longitudinal ends **34**.

In at least some examples, the stiffness of the rods **30** is sufficient to provide mechanical integrity of the shield **10**, and maintain the spatial arrangement of the rods **30** with respect to the frame **20**. However, in at least this example (and in other examples in which the stiffness of the rods **30** is insufficient to provide mechanical integrity to the shield **10** to thereby maintain the spatial arrangement of the rods **30** with respect to the frame **20**), the frame **20** further comprises a top frame member **25** and a bottom frame member **26**, each joined at respective lateral ends thereof to the left frame member **22** and the right frame member **24**.

Optionally, one or a few relatively intermediate vertical members **28** can be provided, linking the top frame member **25** and the bottom frame member **26** together to provide further stiffness to the frame **20**.

In at least some example, the intermediate vertical members **28** can be made from or covered with electrically conducting materials **ME**, and the intermediate vertical members **28** can also have a relatively thin cross-sectional area.

By "relatively thin" in the context of the cross-section of the intermediate vertical members **28** is meant that the cross-section of the intermediate vertical members **28** is about $1/8^{\text{th}}$ to about $1/4$ of the wavelength λ or minimum wavelength λ_{MIN} of the beam **RB**.

In examples in which the intermediate vertical members **28** can be made from or covered with a dielectric material, the cross-sectional area thereof can be greater.

The frame **20** can be made from any suitable mechanically strong material, for example a dielectric material, for example wood or composite materials, fiberglass, Plexiglas, rexolite, Delrin, or for example of a suitable metal, for example steel or aluminum;

in other examples the frame can be constructed from honeycomb panels, for example. At least one or more of the top frame member **25**, bottom frame member **26**, left frame member **22** and right frame member **24** can be made from concrete, for example.

In examples in which at least the left frame member **22** and the right frame member **24**, and in particular the intermediate vertical member(s) **28**, are made from a metal, the relative thin or small cross-section of these frame members in relation to the cross-section of the shield **10** (along a plane parallel to the third plane **P3**) is very small, for example and can be not greater than $1/8^{\text{th}}$ to about $1/4$ of the wavelength λ or minimum wavelength λ_{MIN} of the beam **RB**, and without being bound to theory is expected by the inventors to provide insignificant disruption to the beam **RB**.

The height dimension **HD** and the length dimension **LD** of the shield **10** are such as to ensure that the rods fully traverse the length and height of the cross-section of the channel **CH** in which the shield **10** is placed. This is done such as to ensure that the radio beam **RB** passes through the rods **30** in a uniform manner when the radio beam **RB** is steered throughout the entirety of the azimuth and elevation ranges thereof. Without being bound to theory, inventors consider that as the electromagnetic waves of the radio beam **RB** pass through the rod arrangement of the shield, the phase of the beam changes, and thus such an arrangement in which the radio beam **RB** passes through the rods **30** in a uniform manner throughout the entirety of the azimuth and elevation ranges ensures that the electromagnetic waves of the radio beam **RB** are all in phase during such steering.

Referring also to Figs. 2A, 3A, and 3B, the height dimension **HD** of the shield **10** is such that the top surface **ST** of the channel **CH** intersects the uppermost rod **30** of the shield **10** (marked in Fig. 3B as rod **30A**) and the bottom surface **SB** is close to (or as close to as possible, or abutting, or intersecting) the lowermost rod **30** of the shield **10** (marked in Fig. 3B as rod **30B**), and the length dimension **LD** is such that the right side surface **SSR** and the left side surface **SSL** each intersect all of the rods **30** of the shield. Thus, the beam **RB** essentially traverses the rods **30** of the shield **10** throughout the azimuth and elevation operating ranges of the scanning volume, and ensures that the planarity of the phase of the electromagnetic energy of the beam **RB** is maintained unchanged.

As disclosed above, the shield **10** comprises a plurality of rods **30**, the rods **30** being in parallel spatial relationship one to another. By parallel arrangement is meant herein that

the respective longitudinal axes **LA** are parallel to one another. Furthermore, as mentioned above, referring again to Fig. 4, the longitudinal axes **LA** of the plurality of rods **30** included in the shield **10** can be included fully in a single third plane **P3**, or can be divided into a number of groups wherein in each group the respective longitudinal axes **LA** are included in a respective third plane **P3** of a plurality of mutually parallel third planes **P3**. The one or more respective third planes **P3** is/are orthogonal to the first plane **P1**. In at least this example, the one or more respective third planes **P3** is/are orthogonal to the horizontal plane **HP**.

In at least this example, the one or more respective third planes **P3** is/are parallel to the front face **FF** of the antenna **100**. However, in at least some alternative variations of this example, the one or more respective third planes **P3** can be inclined with respect to the front face **FF** of the antenna.

In one example of such an arrangement for the rods **30** in the shield **10**, and referring to Fig. 5, the rods **30** are co-planarly arranged in spatial arrangement with respect to one another in frame **20** such that the longitudinal axes **LA** of all the rods **30** lie on a single third plane **P3**. In at least this example, the inter-rod center spacing **IRC** between adjacent longitudinal axes of each respective pair of adjacent rods **30** is in the order of 1/4 of the respective operating wavelength λ (i.e., $\text{IRC} \cong 0.25 * \lambda$) for example between 0.2 and 0.3 of respective operating wavelength λ of the antenna **100**. In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range $R\lambda$, the inter-rod center spacing **IRC** between adjacent longitudinal axes of each respective pair of adjacent rods **30** is for example in the order of 1/4 of the respective minimum wavelength λ_{MIN} of the respective operating wavelength range $R\lambda$ (i.e., $\text{IRC} \cong 0.25 * \lambda_{\text{MIN}}$) for example between 0.2 and 0.3 of respective operating minimum wavelength λ_{MIN} .

In at least some examples, the inter-rod center spacing is about 30mm.

In another example of such an arrangement for the rods **30** in the shield **10**, and referring to Fig. 6, the rods **30** are in spatial arrangement with respect to one another in frame **20** such that the plurality of rods **30** are divided into two groups, each group comprising an approximately equal number of rods **30**. The rods **30** of the first group **G_A** are co-planarly arranged with respect to one another such that the longitudinal axes **LA** of all the respective rods **30** lie on a first third plane **P3_A**. The rods **30** of the second group **G_B** are arranged with

respect to one another such that the longitudinal axes **LA** of all the respective rods **30** lie on a second third plane **P3B**. The first third plane **P3A** and the second third plane **P3B** are parallel to one another, and spaced from one another by an inter-plane spacing **IPS**.

In at least this example, the inter-plane spacing **IPS** is in the order of 1/4 of the respective operating wavelength λ (i.e., $\text{IRC} \cong 0.25 * \lambda$) for example between 0.2 and 0.3 of respective operating wavelength λ of the antenna **100**. In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range **R λ** , the inter-plane spacing **IPS** is for example in the order of 1/4 of the respective minimum wavelength λ_{MIN} of the respective operating wavelength range **R λ** (i.e., $\text{IRC} \cong 0.25 * \lambda_{\text{MIN}}$) for example between 0.2 and 0.3 of respective operating minimum wavelength λ_{MIN} .

In at least some examples, the inter-plane spacing **IPS** is about 30mm.

In at least this example, the inter-rod center spacing **IRC** between adjacent longitudinal axes of each respective pair of adjacent rods **30** in each one of the first group **G_A** and the second group **G_B** is in the order of 1/4 of the respective operating wavelength λ (i.e., $\text{IRC} \cong 0.25 * \lambda$) for example between 0.2 and 0.3 of respective operating wavelength λ of the antenna **100**. In applications of at least this example, in which the respective antenna **100** operates in an operating wavelength range **R λ** , the inter-rod center spacing **IRC** between adjacent longitudinal axes **LA** of each respective pair of adjacent rods **30** in each one of the first group **G_A** and the second group **G_B** is in the order of 1/4 of the respective minimum wavelength λ_{MIN} of the respective operating wavelength range **R λ** (i.e., $\text{IRC} \cong 0.25 * \lambda_{\text{MIN}}$) for example between 0.2 and 0.3 of respective operating minimum wavelength λ_{MIN} .

In at least this example, the rods **30** of the first group **G_A** and the rods **30** of the second group **G_B** are staggered arrangement in a direction parallel to the first third plane **P3A** and the second third plane **P3B**, this direction also being orthogonal to the respective longitudinal axes **LA**. In at least this example, such a direction is also nominally or generally vertical, when the shield **10** is installed with respect to the antenna **100**.

In the aforesaid staggered arrangement, each of the rods **30** of the first group **G_A** are intercalated with respect to an adjacent pair of rods **30** of the second group **G_B**. Thus, in a direction parallel to the first third plane **P3A** and the second third plane **P3B**, and orthogonal to the respective longitudinal axes **LA**, the respective longitudinal axis **LA** of each rod of

the first group **G_A** is spaced from the longitudinal axis **LA** of an adjacent rod **30** of the second group **G_B** by an intercalated spacing **ICS**. In at least this example, the intercalated spacing **ICS** is nominally half of the inter-rod center spacing **IRC**.

In yet other example of such an arrangement for the rods **30** in the shield **10**, and referring to Fig. 7 and Fig. 8, the rods **30** are in spatial arrangement with respect to one another in frame **20** such that the plurality of rods **30** are divided into three groups or four groups, or more than four groups. Each such group comprises an approximately equal number of rods **30** co-planarly arranged in a similar to the examples of Fig. 5 or Fig. 6, *mutatis mutandis*. Thus, in each respective group, the respective rods thereof are aligned on a respective third plane **P3**, and spaced from one another by a respective inter-rod center spacing **IRC**, the third planes **P3** of each pair of adjacent third planes being spaced from one another by a respective inter-plane spacing **IPS**.

Furthermore, the rods **30** of each serially successive group of rods is staggered with respect to rods of at least the next adjacent group, in the forward or aft direction.

In one example of such staggering, and referring to Fig. 7 in particular, each of the rods **30** of one group are intercalated with respect to an adjacent pair of rods **30** of an adjacent group. Thus, in a direction **DR** parallel to the respective third planes **P3** and orthogonal to the respective longitudinal axes **LA**, the respective longitudinal axis **LA** of each rod of one such group is spaced from the longitudinal axis **LA** of an adjacent rod **30** of the adjacent group by an intercalated spacing **ICS**. In at least this example (and in the example of Fig. 6) the intercalated spacing **ICS** is nominally half of the inter-rod center spacing **IRC**. Thus, in the example of Fig. 7, the stagger pattern essentially repeats every two adjacent groups, and multiple rods **30** from every other group are aligned along this direction **DR**.

In another example of such staggering, and referring to Fig. 8 in particular, the rods **30** of each successive group are progressively intercalated with respect to an adjacent pair of rods **30** of an adjacent group, in an aft to forward direction along a direction **DR**. As before, direction **DR** is parallel to the respective third planes **P3** and orthogonal to the respective longitudinal axes **LA**. In each successive group, the respective longitudinal axis **LA** of each rod thereof is spaced from the longitudinal axis **LA** of an adjacent rod **30** of the adjacent group by an intercalated spacing **ICS**. In at least this example, the intercalated spacing **ICS** is nominally a fraction $1/n$ of the inter-rod center spacing **IRC**. If there are three

or more such groups, "n" can be an integer at least equal to 3, and thus the intercalated spacing **ICS** is 1/3 of the inter-rod center spacing **IRC**. In the illustrated example of Fig. 8, there are four such groups, and n has an integer value of 4, such that the intercalated spacing **ICS** is 1/4 of the inter-rod center spacing **IRC**.

Depending on the relative sizes of the respective baseline height dimension or baseline diameter **D**, the intercalated spacing **ICS** and the inter-rod center spacing **IRC**, of the multi-group examples of Figs. 6, 7, 8, the respective staggered arrangement collectively provides a solid or semi-solid wall of rods orthogonal to the direction **DR**, i.e., when viewed along the direction **DR**, thereby essentially covering the inter-rod gaps **IRG** of one group of rods by the rods of one or more successive groups of rods.

In at least some example, and referring to Fig. 9, the respective shield comprises one or more dielectric sheets **40**, in nominally parallel relationship with respect to the one or more third planes **P3**.

The dielectric sheets **40** are configured for providing a level of protection to the antenna **100** for the effects of an impact on the shield **10**. For example, the dielectric sheets are about 1mm thick and made from polycarbonate materials.

While in at least the example of Fig. 9, two dielectric sheets **40** are provided, one at the forward face **SFF** and the other at the aft face **SAF** of the shield **10**, in at least some alternative variations of this example, a single dielectric sheet can be provided either at the forward face **SFF** or at the aft face **SAF** of the shield **10**. While in the example of Fig. 9 two groups of rods are illustrated, similar to the example of Fig. 6, it is contemplated that the one or two dielectric sheets, forward and/or aft of the shield, can be provided for any example of the shield, for example comprising a single group of rods (for example similar to but not limited to the example of Fig. 5), or for examples having multiple groups of rods (for example similar to but not limited to the examples of Figs. 7 or 8).

Optionally, and as illustrated in Fig. **10**, additional intermediate dielectric sheets **40'** can be provided within the shield **10**, for example in the spacing between adjacent groups of rods.

In at least some alternative variations of the example of Fig. 10, the dielectric sheets **40** at the forward face **SFF** and at the aft face **SAF** of the shield **10** can be omitted, leaving

only one or more intermediate dielectric sheets **40'**. In at least some other alternative variations of the example of Fig. 10, the dielectric sheets **40** at the forward face **SFF** or at the aft face **SAF** of the shield **10** can be omitted, leaving the other external dielectric sheet plus one or more intermediate dielectric sheets **40'**.

In at least some examples, the respective frame member **20** can be provided exclusively by one or more dielectric sheets **40** and/or intermediate dielectric sheets **40'**, which provide the necessary mechanical support for the rods **30**, which are secured thereto.

In at least some alternative variations of the examples of Figs. 5 to 10, the entire spacing between the rods can be filled with a dielectric substance for example a solid foam, for example rohacell foam or polystyrene foam. In at least the examples of Fig. 9 and 10, the dielectric sheets **40** at the forward face **SFF** and at the aft face **SAF** of the shield **10**, and/or one or more intermediate dielectric sheets **40'**, can be omitted or can be retained. In at least some alternative variations of the above examples, the rods **30** are affixed to the frame **20** via a shock absorber arrangement. In at least one example of such a shock absorber arrangement, the longitudinal ends of the rods **30** are accommodated in oversized openings in the frame **20**, and the spacing between the rod longitudinal ends and the respective oversized openings are filled with a dampening material. In this manner, when the rods **30** are impacted by a threat, such an impact can be dampened by the shock absorber arrangement.

In operation of the antenna **100** with the shield **10** installed forward of the forward face **FF**, the radio beam **RB** is emitted from and exits the antenna **100** and passes through the shield **10** with little or no interference of the amplitude, frequency, or intensity of the radio beam **RB**.

Without being bound to theory, inventors consider that the electromagnetic waves of the radio beam **RB**, when encountering the curved rods **30**, act like creeping waves and essentially creep around the rods **30** from one diametric end thereof facing the antenna **10**, to the other end thereof facing away from the antenna **100**, and then continues along the steered direction after exiting the shield **10**.

As disclosed above, and referring again to Fig. 2B, each rod **30** also has a curved transverse cross-section **CC**. While by "curved" is meant herein to refer being smoothly rounded in a convex manner, and having a single or multiple centers of curvature, the term

"curved" also includes herein high-sided polygonal shapes, having a large number of sides (as well as relatively large angles defined at all the polygon corners) to resemble a curved shape, and such that provides a similar creeping wave effect to the electromagnetic waves emitted/received by the antenna. For example, the number of sides can be greater than 8, and the angles at the corners can exceed 140° , and thus includes for example regular polygons such as for example nonagons, decagons and so on up to chiliagon (having a thousand sides), or polygons with more than one thousand sides.

In the method claims that follow, alphanumeric characters and Roman numerals used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps.

Finally, it should be noted that the word "comprising" as used throughout the appended claims is to be interpreted to mean "including but not limited to".

While there has been shown and disclosed examples in accordance with the presently disclosed subject matter, it will be appreciated that many changes can be made therein without departing from the spirit of the presently disclosed subject matter.

CLAIMS:

1. A shield for an antenna, the shield comprising a plurality of rods, each rod having at least an external surface made from an electrical conducting material, the rods being in parallel spatial relationship one to another, the rods each having a respective curved transverse cross-section.
2. The shield according to claim 1, wherein the external surface covers a dielectric core.
3. The shield according to claim 1, wherein the rods are made from the same or different said electrical conducting material.
4. The shield according to any one of claims 1 to 3, wherein the shield is in the form of a parallelepiped, having a forward face and an aft face, the shield having a lateral length dimension, a height dimension, and a thickness dimension.
5. The shield according to any one of claims 1 to 4, wherein in said parallel spatial relationship the rods are spaced from one another by respective gaps, wherein said inter rod gaps are empty.
6. The shield according to any one of claims 1 to 4, wherein in said parallel spatial relationship the rods are spaced from one another by respective gaps, and wherein said gaps are filled, partially or fully, with a suitable dielectric material.
7. The shield according to any one of claims 1 to 6, wherein each said rod is elongate and extends rectilinearly along a respective longitudinal axis between a respective first longitudinal end and a respective second longitudinal end, and wherein optionally in said parallel relationship, the respective longitudinal axes of the rods are parallel to one another.
8. The shield according to any one of claims 1 to 7, wherein each said curved transverse cross-section has a baseline height dimension.
9. The shield according to claim 8, wherein each said curved transverse cross-section is circular, and wherein the baseline height dimension is a baseline diameter of the transverse cross-section.

10. The shield according to claim 8, wherein each said curved transverse cross-section is egg-shaped oval or elliptical, and wherein the baseline height dimension is a dimension of a respective minor axis of the respective egg-shaped oval or elliptical transverse cross-section.
11. The shield according to any one of claims 1 to 10, wherein each said rod has a uniform said transverse cross-section along the length thereof.
12. The shield according to any one of claims 8 to 11, wherein all the rods comprised in the shield have the same cross-sectional baseline height dimensions.
13. The shield according to any one of claims 8 to 12, including one of the following:
 - wherein an operating frequency of the antenna is 2.4 gigahertz, and wherein the baseline height dimension is about 12mm, or about 16mm, or in the range 12mm to 16mm;
 - wherein an operating frequency of the antenna is 4.8 gigahertz, and wherein the baseline height dimension is about 6mm, or about 8mm, or in the range 6mm to 8mm.
14. The shield according to any one of claims 1 to 13, wherein said rods are made from one or more materials and are so dimensioned and so shaped so as to together provide physical characteristics sufficient such as to provide mechanical protection to the antenna when the shield is interposed between the antenna and a source of an in-coming threat.
15. The shield according to claim 14, wherein said physical characteristics include one or more of: mechanical strength, ductility, toughness, thickness, density, of the material.
16. The shield according to any one of claims 1 to 15, wherein said rods are made from a mechanically resistant metal.
17. The shield according to any one of claims 1 to 16, wherein said rods are made from or comprise any one of or combination of: steel, stainless steel, tungsten, chromium, titanium, iron.

18. The shield according to any one of claims 8 to 17, wherein said baseline height dimension is significantly greater than $1/20^{\text{th}}$ of the respective operating minimum wavelength of the antenna.
19. The shield according to any one of claims 8 to 17, wherein said baseline height dimension is less than or about $1/8^{\text{th}}$ or less than a respective operating minimum wavelength of the antenna, and wherein said baseline height dimension is greater than $1/20^{\text{th}}$ of the respective operating minimum wavelength of the antenna.
20. The shield according to any one of claims 6 to 19, wherein the longitudinal axes of the respective said rods accommodated in the shield are fully included in planar aligned arrangement with respect to a single plane.
21. The shield according to claim 20, wherein the single plane is orthogonal to a propagation direction of an electromagnetic beam transmitted and/or received by the antenna at zero azimuth and 0° elevation.
22. The shield according to any one of claims 20 to 21, wherein in said single plane an inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods is in the order of $1/4$ of the respective operating minimum wavelength of the antenna, and wherein optionally the inter-rod center spacing is about 30mm.
23. The shield according to any one of claims 6 to 19, wherein the longitudinal axes of the respective said rods accommodated in the shield are divided into a number of groups, wherein in each said group the respective longitudinal axes are included in planar aligned arrangement with respect to a respective plane of a plurality of mutually parallel planes.
24. The shield according to claim 23, wherein each said respective plane is orthogonal to a propagation direction of an electromagnetic beam transmitted and/or received by the antenna at zero azimuth and 0° elevation.
25. The shield according to any one of claims 23 to 24, wherein in said respective plane an inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods is in the order of $1/4$ of the respective operating minimum wavelength of the antenna, and wherein optionally the inter-rod center spacing is about 30mm.

26. The shield according to any one of claims 23 to 25, wherein each pair of adjacent said planes are spaced from one another by an inter-plane spacing, and wherein the inter-plane spacing is in the order of $1/4$ of the respective operating minimum wavelength of the antenna.
27. The shield according to claim 26, wherein the inter-plane spacing is about 30mm.
28. The shield according to any one of claims 23 to 27, wherein for each pair of adjacent said planes, the respective rods of one said adjacent plane are in staggered arrangement with respect to the respective rods of the other said adjacent plane.
29. The shield according to claim 28, including one of the following:
 - wherein in said staggered arrangement, each of the rods of one said adjacent plane are intercalated with respect to an adjacent pair of said rods of the other said adjacent plane;
 - wherein in said staggered arrangement, each of the rods of one said adjacent plane are intercalated with respect to an adjacent pair of said rods of the other said adjacent plane by an intercalation spacing equal to half of the inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods;
 - wherein in said staggered arrangement, each of the rods of one said adjacent plane are intercalated with respect to an adjacent pair of said rods of the other said adjacent plane by an intercalation spacing less than half of the inter-rod center spacing between adjacent longitudinal axes of each respective pair of adjacent rods.
30. The shield according to any one of claims 1 to 29, comprising a frame structure configured for mechanically fixing the rods in said parallel spatial relationship one to another.
31. The shield according to claim 30, wherein the frame structure includes a first frame member laterally spaced from a second frame member, each in orthogonal relationship with respect to the respective longitudinal axes of the rods, and wherein the rods are mechanically fixed to the first frame member via the respective first longitudinal ends

of the rods, and wherein the rods are mechanically fixed to the second frame member via the respective second longitudinal ends of the rods.

32. The shield according to claim 31, wherein the frame structure further comprises a top frame member and a bottom frame member, each joined at respective lateral ends thereof to the first frame member and the second frame member.
33. The shield according to claim 32, wherein the frame structure comprises one or more thin cross-sectioned intermediate vertical members, each said thin cross-sectioned intermediate vertical member linking the top frame member and the bottom frame member to one another.
34. The shield according to any one of claims 30 to 33, wherein the frame structure is made from any suitable dielectric material or from a metal.
35. The shield according to any one of claims 30 to 34, wherein the rods are mounted to the frame via a first shock absorber arrangement.
36. The shield according to any one of claims 1 to 35, comprising one or more dielectric sheets, in nominally parallel relationship with respect to a forward face of the shield, the one or more dielectric sheets being configured for providing a level of protection to the antenna, and optionally comprising at least one of the following: one said dielectric sheet affixed to the forward face; one said dielectric sheet fixed to an aft face of the shield; at least one said dielectric sheet fixed within the shield.
37. The shield according to any one of claims 1 to 36, comprising a foam material filling spaces between the rods.
38. An antenna installation, comprising:
 - an antenna having a forward antenna face for emitting and/or receiving electromagnetic radiation;
 - a shield as defined in any one of claims 1 to 37, spaced forward of said forward antenna face by a forward spacing.
39. The antenna installation according to claim 38, wherein the shield is operative for providing protection to the antenna for threats originating in a direction towards the

forward antenna face, wherein said direction is included within a channel defined by a respective maximum azimuth range and a maximum elevation range of the antenna.

40. The antenna installation according to claim 39, wherein the respective maximum azimuth range is $\pm 60^\circ$, and the respective maximum positive elevation of the antenna is $\pm 60^\circ$.
41. The antenna installation according to any one of claims 39 to 40, wherein the channel diverges and increases a cross-sectional area thereof in a forward direction away from the forward antenna face.
42. The antenna installation according to any one of claims 39 to 41, wherein a height dimension of the shield and the length dimension of the shield are such as to ensure that the respective rods fully traverse a length and a height of a cross-section of the channel corresponding to a location of the shield in the channel.
43. The antenna installation according to any one of claims 39 to 42, wherein the channel is defined by a top surface, a bottom surface, a right side surface and a left side surface, wherein a height dimension of the shield is such that the top surface of the channel intersects an uppermost said rod of the shield, and such that the bottom surface of the channel is any one close to abutting, or intersecting, a lowermost said rod of the shield, and wherein a length dimension of the shield is such that the right side surface and the left side surface of the channel each intersect all of the rods of the shield.
44. The antenna installation according to any one of claims 39 to 43, including a protection structure configured for providing at least protection from a threat having a trajectory towards the antenna that avoids crossing into the channel and that is towards the antenna, and wherein optionally the protection structure comprises a peripheral wall and a top wall.
45. The antenna installation according to claim 44, comprising a second shock absorber arrangement interconnecting the shield to the protection structure.
46. The antenna installation according to any one of claims 38 to 45, wherein the antenna is any one of:
 - a static phased array antenna;
 - a static radio antenna or a static TV antenna;

- a revolving antenna, in which the shield is mechanically coupled to the antenna, and wherein the shield and the antenna revolve as a unit about the rotation axis of the antenna.
47. The antenna installation according to any one of claims 38 to 46, wherein the antenna is any one of: a passive electronic scanned array (PESA); an active electronically scanned array (AESA); a hybrid beam forming phased array; a digital beam forming (DBF) array; or a conformal antenna in which individual antennas are arranged on a curved surface, and phase shifters operate to enable the conformal antenna to generate a plane wave.
48. The antenna installation according to any one of claims 38 to 47, wherein the antenna is operative to generate a steerable radio beam having a propagation direction, the radio beam having an oscillating electric field along an electric field plane, and wherein said longitudinal axes of the respective rods are non-parallel with respect to the electric field plane.
49. The antenna installation according to claim 48, wherein said radio beam is operable at a radio frequency range in any one or more of the X-band, S-band, C-band, or L-band.
50. A method for protecting an antenna, the antenna having a forward antenna face for emitting and/or receiving electromagnetic radiation, the method comprising:
- (I) providing a shield as defined in any one of claims 1 to 37,
 - (II) spacing the shield forward of said forward face.