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(54) **Protective composite structure with low radar visibility having integrated attack signaling system**

(57) A ballistic protection panel, characterized in that it possesses at least one external protective layer, at whose interior at least one condenser is situated, constituted by two carbon fiber layers in which the external layer has a matrix with at least 3% nanotubes and the

internal layer has a matrix with at least 6% nanotubes and being equipped with an intermediate dielectric layer, said condenser being connected with at least one electric microcircuit coupled with at least one transmitting unit.

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**Description**State of the art

[0001] Up to now, numerous composite structures in panel form have been produced and patented, adapted to obtain an improved invulnerability from hostile attacks of various nature. Ballistic protections have always been the object of in-depth studies and research, mainly directed towards increasing the inviolability thereof, containing the weight of the armor-plate within parameters that allow such protections to be installed on vehicles and aircraft as well. On the market, there are metal alloys, steel alloys, titanium alloys and aluminum alloys that are highly resistant but negatively affected by serious weight problems. The different chemical-physical characteristics of composite materials, and especially of the compounds associated with carbon chemistry, have instead allowed considerably increasing the protective capacity of any one armored panel, at the same time maintaining a weight per surface unit that is substantially limited. The improved structural characteristics of the advanced composite materials have indeed allowed more efficient armor-plating, above all with regard to latest-generation perforating projectiles. Composite armor-plate technology has found extensive use in recent designs, from armored reconnaissance vehicles to assistance vehicles and armored assault vehicles. Advanced composites are however most preferably used in aircraft vehicles, independent of whether these are helicopters or airplanes. Their intrinsic lightness together with their high projectile absorption capacity has rendered carbon composites the preferred material for the entire aeronautics industry. An advantage which has led to considerable advances in the study of advanced polymers, identifying a plurality of composites with particular characteristics expressly made for resisting repeated hostile attacks. Notwithstanding this diffusion and specialization, ballistic protections made of composite materials, which are also provided with the capacity to signal the area of the vehicle hit by a specific external attack, are not currently available on the market.

Field of the invention

[0002] The present patent application intends to solve the aforesaid lack by describing an innovative ballistic protection made of advanced composite materials and provided at its interior with an integrated nanostructure system capable of automatically and autonomously signaling to a remote station which portion of the vehicle is subjected to hostile attack. The ballistic protection, object of the present industrial patent application, allows automatically and autonomously informing the remote station, possibly identified with the military command itself, with regard to the precise positioning of the vehicle at the time of the attack, identifying in detail even the portion of the armor-plate that was hit by the enemy attack unequivocally identifying it. The system that is the object of the present invention, when activated by the enemy attack, automatically also provides the identification of the vehicle under attack. The ballistic protection system that is the object of the present patent, due to the use of a plurality of carbon layers, claims an extremely favorable stopped weight/caliber ratio, the composite material resulting ideal for the protection of aircraft and helicopters of any type and for any use.

[0003] The ballistic protection system that is the object of the present patent, having an external coating ranging from 6 to 12 mm, preferably 8 mm, made from multilayers of nanostructured epoxy resin, allows reducing by over 25 Db/m<sup>2</sup> the reflection of EM microwaves emitted by any one radar source in a range of frequencies comprised between the X band and the Ku band. This characteristic significantly reduces the radar traceability of the vehicle thus equipped. The present invention generally refers to ballistic protection systems preferably applied on aircraft, helicopters and armored vehicles of various type, referring to the defense industry, proposing an innovative ballistic protection adapted to be employed on any one land, amphibian or aquatic vehicle in addition to being employable on aircraft, helicopters and ships independent of their size.

Description of the invention

[0004] The present invention intends to describe an innovative armor-plate system characterized by the presence of a multiplicity of synthetic polymer layers that are superimposed and integrated with each other, having the following structure:

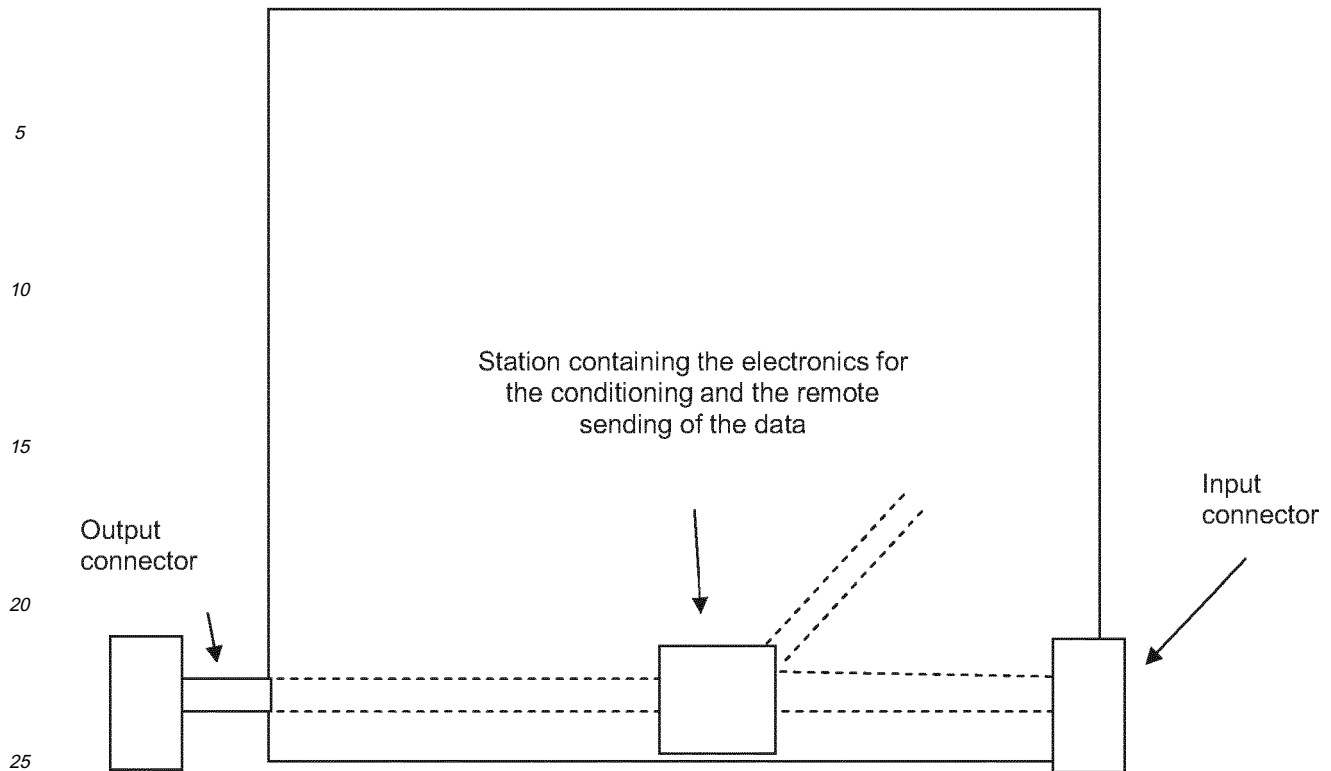
- a) a first external structural layer characterized by a thickness comprised between 1 and 10 mm, preferably 8 mm, made from multilayers of epoxy resin, in a manner so as to allow reducing by over 25 Db/m<sup>2</sup> the reflection of EM microwaves emitted by any one radar source in a range of frequencies comprised between the X band and the Ku band.
- b) A second layer constituted by a skin, preferably made of carbon fiber, with matrix equipped with at least 3% nanotubes. This skin essentially constitutes the armor of the condenser and has a thickness which varies from 0.5 ad 1 mm.

- c) An electronic microcircuit, installed on a common laminated sheet and equipped with four conductive tracks, coupled to the second layer and equipped with a connection to a common transmitting unit.
- d) A structural adhesive layer.
- e) A layer constituted by a dielectric skin made of glass fiber with polyurethane matrix provided with a thickness comprised between 0.5 and 3 mm.
- f) A layer constituted by one or more carbon fiber skins with 6% nanotubes matrix. This layer represents the armor of the condenser and has a thickness from 0.5 to 1 mm.
- g) A structural adhesive layer characterized by a thickness comprised between 0.1 and 0.5 mm.
- h) A layer of pre-impregnated carbon fiber with thickness comprised between 0.3 and 1 mm.
- i) A structural adhesive layer with thickness comprised between 0.1 and 0.5 mm.
- l) A layer of ceramic tiles characterized by the thickness of 3 to 20 mm,
- m) A structural adhesive layer with thickness from 0.1 to 0.5 mm
- n) A layer of pre-impregnated carbon fiber with thickness from 0.3 to 1 mm.
- o) A structural adhesive layer with thickness from 0.1 to 0.5 mm.
- p) A final internal layer made of high-density polyethylene laminate or made of Kevlar with thickness comprised between 10 and 40 mm with epoxy, phenolic or polyester matrix.

**[0005]** The ballistic protection panel obtained according to that described above signals when it is hit; this is due to the electronic microcircuit installed in the third layer, which is provided with four conductive tracks connected to a transmitter capable of detecting a variation of even a few milliwatt. Said variation of a few milliwatt is due to the perforation of the second layer by a projectile, altering such layer's conductive capacity since this is equipped with 3% nanotubes.

**[0006]** The above-described panel can have different sizes and can assume any shape, so long as its internal structure remains intact. Given that it is installable on a variety of vehicles - land, amphibian, marine and air - its thicknesses can be suitably varied; according to the desired specifications, the panel can have greater strength or greater lightness, in any case remaining within the above-described application ranges.

**[0007]** The armor-plate layers of the present invention capable of identifying the part of the vehicle that was hit by a projectile are the second, the third, the fifth and the sixth layer. The second layer is constituted by a skin, preferably made of carbon fiber, with matrix equipped with at least 3% nanotubes. This skin essentially constitutes the external layer of the armor of the condenser and has a thickness which varies from 0.5 to 1 mm. The third sheet is an electronic microcircuit, installed on a laminated sheet and equipped with four conductive tracks, coupled to the second layer and equipped with a connection to a common transmitting unit. The fifth layer is constituted by a dielectric skin made of glass fiber with polyurethane matrix or a layer of high-density polyethylene and is provided with a thickness comprised between 0.5 and 3 mm. The sixth layer is a layer constituted by one or more carbon fiber skins with 6% nanotubes matrix. This layer represents the armor of the condenser and has a thickness from 0.5 to 1 mm. The second and the sixth layer are charged by the thermo-electric potential difference resulting due to a difference of concentration of nanotubules dispersed therein, 3% in the outermost layer and 6% in the innermost layer. Due to temperature micro-variations, the two layers in question tend to cancel out this potential difference as a function of their different internal structure. This passage gives rise to the current necessary to supply power to the condenser. Naturally, the condenser will have size analogous to that of the panel itself, and this allows the armor-plate system that is the object of the present invention to identify and signal which part of the vehicle has been hit by enemy fire. When a projectile hits the condenser, it creates a variation in the condenser's capacity and it is this variation that is immediately read by the electronic microcircuit connected to the condenser itself. The electronic microcircuit automatically and autonomously sends to a remote station (e.g. to operation headquarters), by means of a common transmitting unit, the information regarding the position of the vehicle hit at the time of the attack, the recognition code of the hit vehicle and the armor-plate portion that was the object of the attack. Naturally, the electronic microcircuit is equipped with an electrical contact point accessible to the control electronics. Each single armored panel according to the present invention will be connected with the transmission unit in order to inform the remote station (the operation headquarters) which and how many panels were hit by projectiles. The data transmission occurs by means of CAN bus according to the following diagram:



**[0008]** The energy consumption of each panel is less than 100 mW and the operative range is from less than 40°C to over 80°C.

**[0009]** Each panel requires a 4-wire connection, 2 wires for the CAN bus transmission system and 2 wires for the power supply. The CAN bus transmission system allows serializing a plurality of armored panels according to the present invention, an identification system allows immediately identifying the panel or panels damaged by a possible projectile. The data coming from the CAN bus can be directly interfaced with the computer system of the vehicle itself on which the panel (object of the present invention) is installed, for immediately providing the detected information. Alternatively, said information can be sent to a remote station, such as the operation headquarters.

**[0010]** The weight of the armored panel according to the present invention is about 50 kg/m<sup>2</sup>. Alternatively, the armored panel that is the object of the present patent application can have the following structure:

a) a first external structural layer characterized by a thickness comprised between 1 to 10 mm, preferably 8 mm, made from multilayers of epoxy resin, in a manner so as to allow reducing by over 25 Db/m<sup>2</sup> the reflection of EM microwaves emitted by any one radar source in a range of frequencies comprised between the X band and the Ku band.

b) A second layer constituted by a skin made of aluminum plate or aluminum alloy. This skin essentially constitutes the armor of the condenser and preferably has a thickness of 0.3 mm, but this can vary from 0.5 to 1 mm.

c) An electronic microcircuit, installed on a common laminated sheet and equipped with four conductive tracks, coupled to the second layer and equipped with a connection to a common transmitting unit.

d) A structural adhesive layer.

e) A layer constituted by a dielectric skin made of glass fiber with polyurethane matrix provided with a thickness comprised between 0.5 and 3 mm.

f) A layer constituted by one or more layers of aluminum plate or of aluminum alloy. This layer represents the armor of the condenser and has a thickness of 0.3 mm, or from 0.5 to 1 mm.

g) A structural adhesive layer characterized by a thickness comprised between 0.1 and 0.5 mm.

h) A layer made of pre-impregnated carbon fiber with thickness comprised between 0.3 and 1 mm.

i) A structural adhesive layer with thickness comprised between 0.1 and 0.5 mm.

l) A layer of ceramic tiles characterized by the thickness from 3 to 20 mm.

m) A structural adhesive layer with thickness from 0.1 to 0.5 mm

n) A layer made of pre-impregnated carbon fiber with thickness from 0.3 to 1 mm.

o) A structural adhesive layer with thickness from 0.1 to 0.5 mm.

p) A final internal layer made of high-density polyethylene laminate or of Kevlar with epoxy, phenolic or polyester

matrix with thickness comprised between 10 and 40 mm.

## Claims

1. A ballistic protection panel **characterized in that** it possesses at least one external protective layer, at whose interior at least one condenser is situated, constituted by two carbon fiber layers in which the external layer has a matrix with at least 3% nanotubes and the internal layer has a matrix with at least 6% nanotubes and being equipped with an intermediate dielectric layer, said condenser being connected with at least one electric microcircuit coupled with at least one transmitting unit.
2. Panel according to claim 1, wherein the external protective layer is an external structural layer made of multilayers of nanostructured epoxy resin adapted to diminish radar reflection.
3. A ballistic protection panel **characterized in that** it is constituted by the following layers:
  - a) a first external structural layer **characterized by** a thickness in the range of 1 to 10 mm, preferably 8 mm, made from multilayers of epoxy resin, in a manner so as to allow reducing by over 25 Db/m<sup>2</sup> the reflection of EM microwaves emitted by any one radar source in a range of frequencies comprised between the X band and the Ku band.
  - b) A second layer constituted by a skin, preferably made of carbon fiber, with matrix equipped with at least 3% nanotubes. This skin essentially constitutes the armor of the condenser and has a thickness which varies from 0.5 to 1 mm.
  - c) An electronic microcircuit installed on a common laminated sheet and equipped with four conductive tracks, coupled to the second layer and equipped with a connection to a common transmitting unit.
  - d) A structural adhesive layer.
  - e) A layer constituted by a dielectric skin made of glass fiber with polyurethane matrix provided with a thickness comprised between 0.5 and 3 mm.
  - f) A layer constituted by one or more carbon fiber skins with 6% nanotubes matrix. This layer represents the armor of the condenser and has a thickness comprised between 0.5 and 1 mm.
  - g) A structural adhesive layer **characterized by** a thickness comprised between 0.1 and 0.5 mm.
  - h) A layer made of pre-impregnated carbon fiber with thickness comprised between 0.3 and 1 mm.
  - i) A structural adhesive layer with thickness comprised between 0.1 and 0.5 mm.
  - j) A layer of ceramic tiles **characterized by** the thickness of 3 to 20 mm.
  - m) A structural adhesive layer with thickness from 0.1 to 0.5 mm
  - n) A layer made of pre-impregnated carbon fiber with thickness from 0.3 to 1 mm.
  - o) A structural adhesive layer with thickness from 0.1 to 0.5 mm.
  - p) A final internal layer made of high-density polyethylene laminate or of Kevlar with epoxy, phenolic or polyester matrix with thickness comprised between 10 and 40 mm.
4. Panel according to the preceding claims, wherein each single panel has a 4-wire connection, 2 wires for the CAN bus transmission system and 2 wires for the power supply.
5. Panel according to the preceding claims, wherein the CAN bus transmission system allows serializing a plurality of armored panels.
6. Panel according to the preceding claims, wherein the weight of the armored panel according to the present invention is about 50 kg/m<sup>2</sup>.
7. Panel according to the preceding claims, **characterized by** the following structure:
  - a) a first external structural layer **characterized by** a thickness comprised in the range of 1 to 10 mm, preferably 8 mm, made from multilayers of epoxy resin, in a manner so as to allow reducing by over 25 Db/m<sup>2</sup> the reflection of EM microwaves emitted by any one radar source in a range of frequencies comprised between the X band and the Ku band.
  - b) A second layer constituted by a layer made of aluminum plate or aluminum alloy. This skin essentially constitutes the armor of the condenser and preferably has a thickness of 0.3 mm, but this can vary from 0.5 to 1 mm.

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- c) An electronic microcircuit, installed on a common laminated sheet and equipped with four conductive tracks, coupled to the second layer and equipped with a connection to a common transmitting unit.
- d) A structural adhesive layer.
- 5 e) A layer constituted by a dielectric skin made of glass fiber with polyurethane matrix provided with a thickness comprised between 0.5 and 3 mm.
- f) A layer constituted by one or more layers of aluminum plate or of aluminum alloy. Said layer represents the armor of the condenser and has a thickness of 0.3 mm, or from 0.5 to 1 mm.
- g) A structural adhesive layer **characterized by** a thickness comprised between 0.1 and 0.5 mm.
- h) A layer made of pre-impregnated carbon fiber with thickness comprised between 0.3 and 1 mm.
- 10 i) A structural adhesive layer with thickness comprised between 0.1 and 0.5 mm.
- l) A layer of ceramic tiles **characterized by** the thickness from 3 to 20 mm.
- m) A structural adhesive layer with thickness from 0.1 to 0.5 mm
- n) A layer made of pre-impregnated carbon fiber with thickness from 0.3 to 1 mm.
- o) A structural adhesive layer with thickness from 0.1 to 0.5 mm.
- 15 p) A final internal layer made of high-density polyethylene laminate or of Kevlar with epoxy, phenolic or polyester matrix with thickness comprised between 10 and 40 mm.

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## EUROPEAN SEARCH REPORT

Application Number  
EP 12 16 4710

| DOCUMENTS CONSIDERED TO BE RELEVANT   |  |                                  |   |
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| The present search report has been drawn up for all claims  |  |                                  | TECHNICAL FIELDS SEARCHED (IPC)         |
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| <p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone<br/>Y : particularly relevant if combined with another document of the same category<br/>A : technological background<br/>O : non-written disclosure<br/>P : intermediate document</p> <p>T : theory or principle underlying the invention<br/>E : earlier patent document, but published on, or after the filing date<br/>D : document cited in the application<br/>L : document cited for other reasons<br/>.....<br/>&amp; : member of the same patent family, corresponding document</p> |  |                                  |   |

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82