

4D UWB RADAR INSPECTION METHOD AND SYSTEM

TECHNICAL FIELD

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The present invention relates to a radar inspection method and system and in particular, to a method and system for time-dependent inspection by ultra wide band (UWB) ground penetrating radar technology.

10 BACKGROUND

Ground penetrating radar (GPR) technology has been used for detection of underground heterogeneous objects such as pipelines, vessels, cables, tunnels and various types of subsurface cavities. While conventional GPR method is capable of detecting the
15 presence and location of such objects, it lacks solution for reliable and efficient inspection and determination of the variance of such objects over time. This is particularly the case where the structure and/or the properties of the objects are slowly and progressively changed over a relatively longer period of time. Such types of changes, for instance voids, cracks or water-leaking under highways or airport runways, may potentially lead to final
20 failure of the construction. It would be desirable to provide a method and system for the inspection of objects to determine whether the size, position, material composition and/or other physical/chemical properties are changed over time. Such a method and system are currently unavailable.

25 SUMMARY OF THE INVENTION

In one aspect, embodiments of the present invention provide a method for inspecting an object by UWB four-dimensional (4D) radar technology. An initial location of the object in a three-dimensional coordinate system is determined. A first three-
30 dimensional profile is obtained corresponding to a first instant and a second three-dimensional profile is obtained corresponding to a subsequent second instant to generate a four-dimensional profile of the object. The first and the second three-dimensional profiles

in the four-dimensional profile are compared and a variance of the object over the time period from the first instant to the second instant can be determined.

5 The first three dimensional profile or second three dimensional profile may include physical and / or chemical properties of the object, e.g. the three-dimensional position coordination of the object in an X-Y-Z coordinate system, the shape, size and composition of the object and a time factor representing the fourth dimension i.e. the time axis. Variance of the object therefore includes situations such as change of positions, change of shape and size or a combination of these changes in the three-dimensional coordinate system and over the time period from the first instant to the second instant. Variance of
10 the object may also include change of material compositions over the time period.

15 In another aspect, embodiments of the present invention provide a system for inspecting an object by UWB radar technology. The system includes an antenna array for directing emitted radar signal towards an object in a three-dimensional coordinate system and receiving reflected radar signal from the object, and a radar transceiving, data processing and controlling unit coupled to the antenna array. The radar transceiving, data processing and controlling unit is to obtain a first three-dimensional profile of the object at a first instant, a second three-dimensional profile of the object at a second instant based on
20 the emitted radar signals and the reflected radar signal to generate a four-dimensional profile of the object, and to compare the first and second three-dimensional profiles in the four-dimensional profile to determine a variance of the object from the first instant to the second instant.

25 Other aspects and advantages of the present invention will become apparent from the following detailed description, illustrating by way of example the inventive concept of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the present invention will be described in detail with reference to the accompanying drawings, in which:

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Fig. 1 is a schematic diagram showing a radar inspection system according to one embodiment of the present invention;

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Fig. 2 is a schematic diagram showing the radar inspection system of Fig. 1 when carrying out a detection operation;

Fig. 3 is a schematic diagram showing a set up of an inspection method according to one embodiment of the present invention;

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Fig. 4 is a schematic diagram showing an inspection result from the method illustrated in Fig. 3;

Fig. 5 is a schematic diagram showing a set up of an inspection method and result according to another embodiment of the present invention;

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Fig. 6 is a schematic diagram showing a set up of an inspection method according to a further embodiment of the present invention;

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Fig. 7 is a schematic diagram showing the positional changes of an object based on the inspection method shown in Fig. 6 and viewing from the X-Y plane;

Fig. 8 is a schematic diagram showing the positional changes of an object based on the inspection method shown in Fig. 6 and viewing from the X-Z plane;

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Fig. 9 is a schematic diagram showing the positional changes of an object based on the inspection method shown in Fig. 6 and viewing from the Y-Z plane.

Figs. 10 to 12 are schematic diagrams showing radar inspection methods according further embodiments of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

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As shown in Fig. 1, a radar inspection system according to one embodiment of the present invention includes a radar transceiving, data processing and controlling unit 80 coupled to an antenna array 70 and a display screen 90. Antenna array 70 includes a plurality of antenna units 72 arranged along X and Y direction to form a matrix. Some of the antenna units may be configured as radar signal emitter and some other antenna units may be configured as radar signal receiver, all centrally controlled by radar transceiving, data processing and controlling unit 80. Alternatively, each individual antenna unit 72 may be configured to perform both the radar signal emitting and receiving functions and controlled by radar transceiving, data processing and controlling unit 80.

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To carry out inspection operation, as shown in Fig. 2, the radar inspection system is brought on site over a selected area of ground surface 100 and with antenna array 70 placed in close proximity to ground surface 100. Emitted radar signals 74 are then directed to pass through ground surface 100 into the underneath area. When emitted radar signals 74 reach a heterogeneous object under the ground surface 100, e.g. object 1 as shown in Fig. 2, reflected radar signals 76 will be generated at the boundary of heterogeneous object 1, returned back through the ground surface 100, and are received by the radar signal receiving units of antenna array 70. By analyzing the characteristics of the emitted radar signals 74 and reflected radar signals 76, e.g. the frequency, amplitude, time, etc., a presence status, the initial location and depth of heterogeneous object 1 in a three-dimensional coordinate system 1010 can be determined.

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Depending on the actual environment and underground condition, the heterogeneous object may be in the form of a void, a cavity, a crack, a buried substance of a different material than the earth, such as a pipe, a steel bar or the like. The heterogeneous object may also be a portion of the same surrounding material but of different physical and/or chemical properties. For example, such types of heterogeneous

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object may be a portion of soil or sand soaked with water, a rusted portion of a metal substance, etc. In addition to the ability for detection of the presence and location of a heterogeneous object, embodiments of the present invention provide solutions for time-based qualitative and quantitative analysis of the characteristics of the heterogeneous object, as illustrated in further details below.

As shown in Fig. 3, based on the initial location of the heterogeneous object 1 determined in a three-dimensional coordinate system 1010 and for data-acquisition purpose, the system defines a plurality of imaginative data-sampling layers 110, 120, 130, 140, 150, 160 and 170 under the ground surface 100. These layers may be selected at appropriate depths and positions based on the quality of the radar signals detected for data processing. The layers may be parallel to the ground surface 100, and are evenly distributed vertically under the ground surface, i.e. with same intervals there between. Alternatively, depending on the nature and properties of the object-to-be-inspected, the data accuracy requirements of the inspection result, etc., the number of layers may be defined and the layers may be distributed according to any arbitrary orientation, position and with different intervals.

In a method according to one embodiment of the present invention, when an initial location of the heterogeneous object 1 is determined, the inspection operations are carried out repeatedly over the same inspection area, each at one of at least two or a series of predetermined time instants. Results of these inspection operations are then comparatively analyzed to provide a four-dimensional profile of the inspected object, i.e. a time-based variance of the object presented together with the position and size in a three-dimensional domain.

At a first instant t_{11} , emitted radar signals from the antenna array 20 are directed through the ground surface 100 towards the position at which the heterogeneous object 1 is detected. Reflected radar signals from the intersections between the heterogeneous object 1 and each data-sampling layer 110, 120, 130, 140, 150, 160 and 170 are captured by the antenna array 70 and processed by radar transceiving, data processing and controlling unit 80. In the embodiment shown in Fig. 3, the heterogeneous object 1 is

smaller than the physical dimension of antenna array 70, hence it is possible that the boundary of the heterogeneous object 1 can be determined while the antenna array 70 is placed above the ground surface 100 and remains stationary relative to the heterogeneous object 1. In situations where a heterogeneous object is bigger than the physical dimension of antenna array 70, the inspection may be performed by scanning the antenna array 70 through the heterogeneous object such that the radar signals can reach all parts of the heterogeneous object.

At each of the data-sampling layers 110, 120, 130, 140, 150, 160 and 170, based on the characteristics of the emitted radar signals and reflected radar signals, two-dimensional (2D) contours 111, 121, 131, 141, 151, 161 and 171 on a respective data-sampling layer can be obtained and result of which can be selectively displayed on screen 90. Each contour corresponds to an intersection of a respective data-sampling layer and the heterogeneous object 1. Shown in Fig. 3 as an example, when layer 130 is selected as shown by an on-screen indicator 92, the contour 131 at layer 130 will be displayed. The shape and position of each contour can also be further ascertained with respect to the X-Y-Z coordinate system 1010 or, alternatively, with respect to one or more reference element, posts or landmarks (only one post 50 is shown) which is preset at a known location of the X-Y-Z coordinate system, and closer to the object-to-be-detected. Based on 2D contours 111, 121, 131, 141, 151, 161 and 171 obtained at each respective data-sampling layer 110, 120, 130, 140, 150, 160 and 170, a first three-dimensional (3D) profile 101 of the heterogeneous object 1 can be determined as an envelope of the 2D contours 111, 121, 131, 141, 151, 161 and 171, as shown in Fig. 4.

At a second instant t12, i.e. after a predetermined time lapse from the first instant t11, the radar inspection system is set up at the same location and with reference to same X-Y-Z coordinate system 1010 for further inspection. Position of the system is verified by e.g. locating the reference post 50 the same manner as that performed at the first instant. The above-illustrated steps are then repeated and a second set of 2D contours 112, 122, 132, 142, 152, 162 and 172 corresponding to each respective data-sampling layer are obtained. The second instant t12 may be selected with a predetermined time interval from the first instant t11, i.e. one hour, one day, one month, etc. based on the time-based

variance nature of the object. Understandably, in the event that the time-based variance nature of the object is unknown, the time interval selected for the inspection operation at the second and subsequent instant may be arbitrarily set first for initial detection and adjusted accordingly to an appropriate value.

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Based on the 2D contours 112, 122, 132, 142, 152, 162 and 172 determined at each respective data-sampling layer 110, 120, 130, 140, 150, 160 and 170 at the second instant, a second 3D profile 102 of the heterogeneous object 1 can be determined as an enveloping surface of the 2D contours 112, 122, 132, 142, 152, 162 and 172, as shown in Fig. 4. A

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4D profile of the object can be generated from the first three-dimensional profile 101 and second three-dimensional profile 102. The 4D profile includes information associated with a position of the object in X-Y-Z coordinate system 1010, the size, shape of the object or a combination of these data, as well as a time factor associated with first instant t11 and second instant t12 recorded on a time-axis 1014 as depicted in Fig. 4. A

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comparative analysis between the first 3D profile 101 and the second 3D profile 102 in the four-dimensional profile can then be made to determine a variance of the heterogeneous object 1 which took place from the first instant to the second instant. Depending on the nature of the heterogeneous object and the requirements of inspection, the above steps may be repeated at further subsequent instants to obtain further 3D profiles of the

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heterogeneous object at each of the subsequent instants, and to generate a 4D profile of the object from first, second and such further 3D profiles. Comparisons between the first, second and one or more of the further 3D profiles in the 4D profile may also be made to determine the variance of the heterogeneous object and/or to predict the trends of the variance. It would be appreciated that according to methods illustrated above, with the inclusion of time-based factors into the inspection operation, identification, determination and/or prediction of potential structural damage and construction failure, e.g. geological hazardous resulted from the heterogeneous object becomes viable, in addition to merely detection of a presence or absence of a heterogeneous object.

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In the example shown in Fig. 4, comparison of the first 3D profile 101 and the second 3D profile 102 shows that, under one possible circumstance, the physical dimension of the heterogeneous object 1 is increased with the time lapse from the first

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instant to the second instant. Understandably, Fig. 4 may represent a situation where the heterogeneous object 1 is an underground cavity, the size of which becomes greater over a time period counted from the first instant to the second instant. It is also possible that Fig. 4 represents another situation where the object 1 is a region filled with the same material as the surrounding portions, but the physical/chemical properties is changed, e.g. by being soaked with leaking water, which is detected as a heterogeneous object necessary for further investigation.

Fig. 5 shows an inspection method and result for investigation of positional changes of an underground heterogeneous object 2, according to another embodiment of the present invention. In a manner similar to that of the previous embodiment, radar signals are transmitted through ground surface 200 and reflected radar signals are received by antenna array 70 for the detection of initial position of heterogeneous object 2. A data-sampling layer 210 is defined at a depth of the heterogeneous object 2 and parallel to ground surface 200. A post 52 is set adjacent to the initial position of the heterogeneous object 20 as a reference to determine any positional change over time of the heterogeneous object 2. Inspections are carried out at a series of selected instants to investigate the displacement of heterogeneous object 2. The inspection is started at a first instant by placing antenna array 70 over the ground surface 200 at the initial position 201. Upon processing and analyzing the data corresponding to the emitted and reflected radar signals at data-sampling layer 210, the initial position and contour of object 2 are obtained which can be displayed on screen 90 as first 3D profile 211. The above process is repeated at each of the selected subsequent instants and based on the profiles 212, 213, 214, 215 and 216 obtained, corresponding positions of the object at each of the subsequent instant can be determined, each being made reference to the position of reference post 52. Profiles 212, 213, 214, 215 and 216 may also be shown in screen 90 for viewing. In the event that inspection is to be carried out at positions of the object which is outside of the effective signal processing range of antenna array 70, the antenna array 70 may be moved to suitable positions (as depicted by dotted lines as antenna array 70' in Fig. 5) to adapt to the new position of the object.

Fig. 5 may be understood to represent a situation where the heterogeneous object 2 is a buried object and the position of the object is shifted over the period of time from the first instant. Based on the profiles obtained, it is also possible to further predict the trends of shifting of the heterogeneous object 2.

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It should be appreciated that while the embodiment shown in Fig. 5 illustrates a situation where an underground heterogeneous object shifts or migrates along a path of the same depth underneath the ground surface, an inspection method according to the invention is also capable of inspecting positional changes of an object across different depths, as illustrated in a further embodiment in conjunction with Figs. 6 to 9.

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Similar to the previous embodiments, one or more posts 53a, 53b are preset as position references for the inspection at each selected instant. As shown in Fig. 6, at a first instant, the position of a heterogeneous object 3 is detected when the object is at first position 301. A first set of data-sampling layers (three layers 310a, 310b and 310c are shown for the purpose of illustration) are defined which intersect the object 3 at the first position 301. Based on the radar signals emitted to and reflected from the respective data-sampling layers 310a, 310b and 310c, a first 3D profile representing the properties of the object 3 at first position 301, e.g. the position, size, shape, composition, etc., is obtained.

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As the position, size and/or shape of the object 3 may be changed after the first instant and along any of X, Y and Z directions, or a combination thereof, the previously defined data-sampling layers 310a, 310b and 310c may no longer be suitable and therefore, the system de-defines new data-sampling layers to better trace the changes of the object 3. Based on the emitted radar signal and reflected radar signal at different depths, the system defines data sampling layers at which the best quality signals are obtained for data analysis. In the example shown in Fig. 6, new data-sampling layers 320a, 320b and 320c are defined which are at positions away from the first set of data-sampling layers 310a, 310b and 310c. The 3D profile of object 3 at position 302 can therefore be determined based on the result of radar signal processing of data acquired at each of the new data-sampling layers 320a, 320b and 320c. The above process may be repeated at each of a series of subsequent instants, and the 3D profiles 303, 304, 305, 306, 307, 308 and 309 of object 3

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at each corresponding position are obtained. With the addition of time factor corresponding to each of the respective 3D profiles, a 4D profile is obtained which provides information on the variance of the object over time i.e. in this embodiment, change of position in the X-Y-Z space over time.

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Figs. 7, 8 and 9 show the inspection results, which is a series of locations of object 3 corresponding to each selected instant. The profile information of object 3 includes the position information at each location plus the time corresponding to each instant. The position information of object 3 at each location includes the 3-dimensional coordinates in the X-Y-Z space. Therefore, the present invention provides solutions for radar inspection of heterogeneous objects on a 4-dimensional basis.

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Figs. 10 to 12 are schematic diagrams showing radar inspection methods according further embodiments of the present invention. In one embodiment showing in Fig. 10, a plurality of imaginative data-sampling layers 410, 420, 430, 440, 450, 460 and 470 under the ground surface 400 are defined. Each layer is perpendicular to the ground surface 400, and parallel to the X-Z plane. Data-sampling layers 410, 420, 430, 440, 450, 460 and 470 defined in this manner are used in a situation where an underground heterogeneous object 4 has the greatest dimension, or possible trends of dimension variance, along a direction generally parallel to the Y-Z plane. During the inspection process, radar signals passing through the ground surface and arriving at the boundaries of the object 4 at the intersection regions of each of the data-sampling layers 410, 420, 430, 440, 450, 460 and 470 are reflected back and captured for further processing and analysis. Corresponding to a first instant t_{41} , first set of 2D contours 411, 421, 431, 441, 451, 461 and 471 at each respective data-sampling layer can be obtained. A first 3D profile 401 is derived from these 2D profiles which reflect the size and dimension of the object 4 in the X-Y-Z space corresponding to first instant t_{41} . Subsequently at a second instant t_{42} , second set of 2D contours 412, 422, 432, 442, 452, 462 and 472 at each respective data-sampling layer can be obtained and likewise, second 3D profile 402 is derived reflecting the size and dimension of the object 4 in the X-Y-Z space at second instant t_{42} . A 4D profile is generated from first and second 3D profiles 401 and 402, and a comparison between the first 3D profile 401 and the second 3D profile 402 in the four-dimensional profile is made

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to determine a variance of the object 4 from the first instant t41 to the second instant t42 which, in the present embodiment, represents a change in shape and dimension of the object 4 from the first instant t41 to the second instant t42.

5 In the embodiment showing in Fig. 11, a plurality of imaginative data-sampling layers 510, 520, 530, 540, 550, 560 and 570 under the ground surface 500 are defined. Each layer is perpendicular to the ground surface 500, and parallel to the Y-Z plane. Data-sampling layers 510, 520, 530, 540, 550, 560 and 570 defined in this manner are used in a situation where an underground heterogeneous object 5 has a greatest dimension, or
10 possible trends of dimension variance, along a direction generally parallel to the X-Z plane. During the inspection process, radar signals arrived at the boundaries of the object 5 at the intersection regions of each of the data-sampling layers 510, 520, 530, 540, 550, 560 and 570 are reflected back and captured for further processing and analysis. Corresponding to a first instant t51, first set of 2D contours 511, 521, 531, 541, 551, 561 and 571 at each
15 respective data-sampling layer can be obtained. A first 3D profile 501 is derived from these 2D profiles which reflect the size and dimension of the object 5 in the X-Y-Z space corresponding to first instant t51. Subsequently at a second instant t52, second set of 2D contours 512, 522, 532, 542, 552, 562 and 572 at each respective data-sampling layer can be obtained and likewise, second 3D profile 502 is derived reflecting the size and
20 dimension of the object 5 in the X-Y-Z space corresponding to second instant t52. A 4D profile is generated from first and second 3D profiles 501 and 502, and a comparison between the first 3D profile 501 and the second 3D profile 502 in the four-dimensional profile is made to determine a variance of the object 5 from the first instant t51 to the second instant t52 which, in the present embodiment, represents a change in shape and
25 dimension of the object 5 from the first instant t51 to the second instant t52.

 In the embodiment showing in Fig. 12, a plurality of imaginative data-sampling layers 610, 620, 630, 640, 650, 660 and 670 under the ground surface 600 are defined. These layers are oriented along an angle not perpendicular to any of the X-Y, X-Z or Y-Z
30 plane, e.g. the angle is between 0 to 90 degrees with respect to the ground surface 600. Data-sampling layers 610, 620, 630, 640, 650, 660 and 670 defined in this manner are used in a situation where an underground heterogeneous object 6 has a greatest dimension,

or possible trends of dimension variance, along a direction generally perpendicular to the angled direction of the data-sampling layers. During the inspection process, radar signals arrived at the boundaries of the object 6 at the intersection regions of each of the data-sampling layers 610, 620, 630, 640, 650, 660 and 670 are reflected back and captured for further processing and analysis. Corresponding to a first instant t62, first set of 2D contours 611, 621, 631, 641, 651, 661 and 671 at each respective data-sampling layer can be obtained. A first 3D profile 601 is derived from these 2D profiles which reflect the size and dimension of the object 6 in the X-Y-Z space corresponding to first instant t61. Subsequently at a second instant t62, second set of 2D contours 612, 622, 632, 642, 652, 662 and 672 at each respective data-sampling layer can be obtained and likewise, second 3D profile 602 is derived reflecting the size and dimension of the object 6 in the X-Y-Z space corresponding to second instant t62. A 4D profile is generated from first and second 3D profiles 601 and 602, and a comparison between the first 3D profile 601 and the second 3D profile 602 in the four-dimensional profile is made to determine a variance of the object 6 from the first instant t61 to the second instant t62 which, in the present embodiment, represents a change in shape and dimension of the object 6 from the first instant t61 to the second instant t62.

Although embodiments of the present invention have been illustrated in conjunction with the accompanying drawings and described in the foregoing detailed description, it should be appreciated that the present invention is not limited to the embodiments disclosed. Therefore, the present invention should be understood to be capable of numerous rearrangements, modifications, alternatives and substitutions without departing from the spirit of the invention as set forth and recited by the following claims.

CLAIMS

1. An Ultra Wide Band radar inspection method comprising:
 - determining an initial location of an object in a three-dimensional coordinate
 - 5 system;
 - obtaining a first three-dimensional profile of the object in said three-dimensional coordinate system at a first instant;
 - obtaining a second three-dimensional profile of the object in said three-dimensional coordinate system at a second instant
 - 10 generating a four-dimensional profile of the object from the first three-dimensional profile and second three-dimensional profile;
 - comparing the first three-dimensional profile and the second three-dimensional profile in the four-dimensional profile to determine a variance of the object from the first instant to the second instant.
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2. The method of claim 1, wherein obtaining the first three-dimensional profile including:
 - defining a plurality of first set of layers across the object, each of the first set of
 - layers intersects with the object at a first boundary;
 - 20 directing, at the first instant, emitted radar signals towards the object;
 - receiving reflected radar signals from the first boundaries;
 - obtaining a plurality of first two-dimensional profiles based on the emitted radar signals and the reflected radar signals, each of the first two-dimensional profiles corresponds to the first boundary in a respective one
 - 25 of the first set of layers;
 - obtaining the first three-dimensional profile based on the plurality of first two-dimensional profiles.
3. The method of claim 2, wherein each of the first set of layers intersects with the
- 30 object at a second boundary, wherein obtaining the second three-dimensional profile including:
 - directing, at the second instant, emitted radar signals towards the object;

receiving reflected radar signals from the second boundaries;
obtaining a plurality of second two-dimensional profiles based on the emitted
radar signals and the reflected radar signals, each of the second two-
dimensional profiles corresponds to a second boundary in a respective layer;
5 obtaining the second three-dimensional profile based on the plurality of second
two-dimensional profiles.

4. The method of claim 3, wherein obtaining the first three-dimensional profile
including:

10 prior to directing at the first instant emitted radar signals towards the object,
locating a reference position;
wherein the plurality of first two-dimensional profiles are associated with the
reference position.

- 15 5. The method of claim 4, wherein obtaining the second three-dimensional profile
including:

prior to directing at the second instant emitted radar signals towards the object,
locating the reference position;
wherein the plurality of second two-dimensional profiles are associated with
20 the reference position.

6. The method of claim 2, wherein the plurality of first set of layers being orientated
parallel to a surface through which the emitted radar signals pass prior to reaching
the object.

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7. The method of claim 2, wherein the plurality of first set of layers being orientated
perpendicular to a surface through which the emitted radar signals pass prior to
reaching the object.

- 30 8. The method of claim 2, wherein the plurality of first set of layers are orientated at
an angle with respect to a surface through which the emitted radar signals pass

prior to reaching the object, wherein the angle is between 0 to 90 degrees with respect to the surface.

9. The method of claim 2, wherein obtaining a second three-dimensional profile including:

5 defining a plurality of second set of layers across the object, each of the second set of layers intersects with the object at a second boundary;
directing, at the second instant, emitted radar signals towards the object;
receiving reflected radar signals from the second boundaries;
10 obtaining a plurality of second two-dimensional profiles based on the emitted radar signals and the reflected radar signals, each of the second two-dimensional profiles corresponds to a second boundary in a respective one of the second layers;
obtaining the second three-dimensional profile based on the plurality of second
15 two-dimensional profiles.

10. The method of claim 9, wherein obtaining the first three-dimensional profile including:

20 prior to directing at the first instant emitted radar signals towards the object,
locating a reference position;
wherein the plurality of first two-dimensional profiles are associated with the reference position.

11. The method of claim 10, wherein obtaining the second three-dimensional profile including:

25 prior to directing at the second instant emitted radar signals towards the object,
locating the reference position;
wherein the plurality of second two-dimensional profiles are associated with the reference position.

12. The method of claim 9, wherein the plurality of second set of layers being orientated parallel to a surface through which the emitted radar signals pass prior to reaching the object.
- 5 13. The method of claim 9, wherein the plurality of second set of layers being orientated perpendicular to a surface through which the emitted radar signals pass prior to reaching the object.
- 10 14. The method of claim 9, wherein the plurality of second set of layers are orientated at an angle with respect to a surface through which the emitted radar signals pass prior to reaching the object, wherein the angel is between 0 to 90 degrees with respect to the surface.
- 15 15. The method of claim 1, wherein the four-dimensional profile includes one or more of a position in said three-dimensional coordinate system, a size, a shape, a composition of said object or a combination thereof and a time factor associated with the first instant and the second instant.
- 20 16. An Ultra Wide Band radar inspection system comprising:
an antenna array for directing emitted radar signal towards an object-in a three-dimensional coordinate system and receiving reflected radar signal from the object;
a radar transceiving, data processing and controlling unit coupled to the antenna array;
25 wherein the radar transceiving, data processing and controlling unit is to obtain a first three-dimensional profile of the object at a first instant, a second three-dimensional profile of the object at a second instant based on the emitted radar signals and the reflected radar signal, to generate a four-dimensional profile of the object from the first three-dimensional profile
30 and second three-dimensional profile and to compare the first and second three-dimensional profiles determine a variance of the object from the first instant to the second instant.

17. The radar inspection system of claim 16, further comprising a position reference element disposed adjacent to the object, wherein the radar transceiving, data processing and controlling unit is to obtain the first and the second three-dimensional profiles with respect to the position reference element.
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