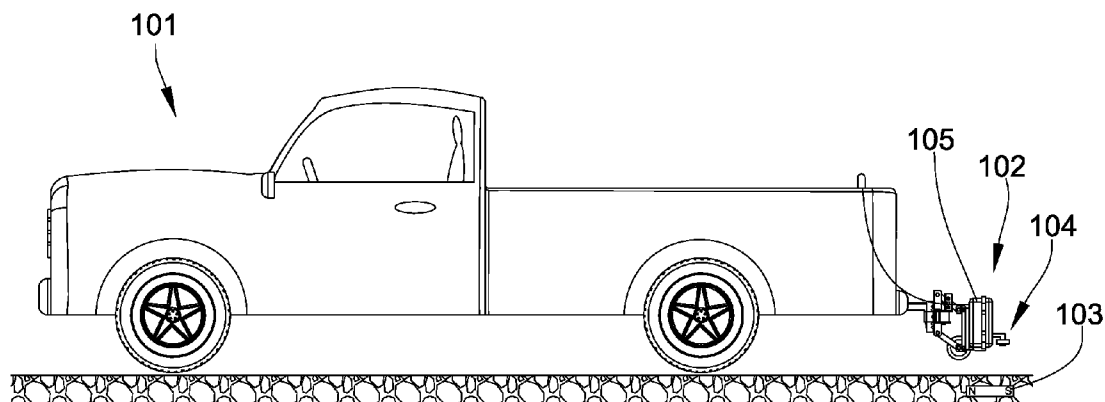




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(19) **United States**(12) **Patent Application Publication**
Hall et al.(10) **Pub. No.: US 2012/0001638 A1**(43) **Pub. Date: Jan. 5, 2012**(54) **ASSEMBLY AND METHOD FOR
IDENTIFYING A FERROUS MATERIAL**(76) Inventors: **David R. Hall**, Provo, UT (US);
David C. Wahlquist, Spanish Fork,
UT (US); **David L. Hyer**,
Springville, UT (US)(21) Appl. No.: **12/827,616**(22) Filed: **Jun. 30, 2010****Related U.S. Application Data**(63) Continuation-in-part of application No. 12/827,525,
filed on Jun. 30, 2010.**Publication Classification**(51) **Int. Cl.**
G01V 3/08 (2006.01)(52) **U.S. Cl.** **324/345**(57) **ABSTRACT**

In one aspect of the present invention, a system assembly for identifying a ferrous material comprises a plurality of magnetometers spaced at varying distances from a ferrous material. Each of the plurality of magnetometers may comprise a sensor reading of a magnitude of an absolute magnetic field, which comprises a magnetic field created by the ferrous material and an ambient magnetic field. One of the plurality of magnetometers may be designated as a primary magnetometer. A distance to the ferrous material from the primary magnetometer may be determined by forming a ratio of the differences in the sensor reading of the primary magnetometer and the sensor readings of the other magnetometers set equal to a ratio of the differences in the distance to the ferrous material from the primary magnetometer inversely cubed and the distances to the ferrous material from the other magnetometers inversely cubed. The system assembly may also comprise a picture taking device that may provide an image of a surface viewable from above the ferrous material and a global positioning system device that may provide a map of a geographical region.



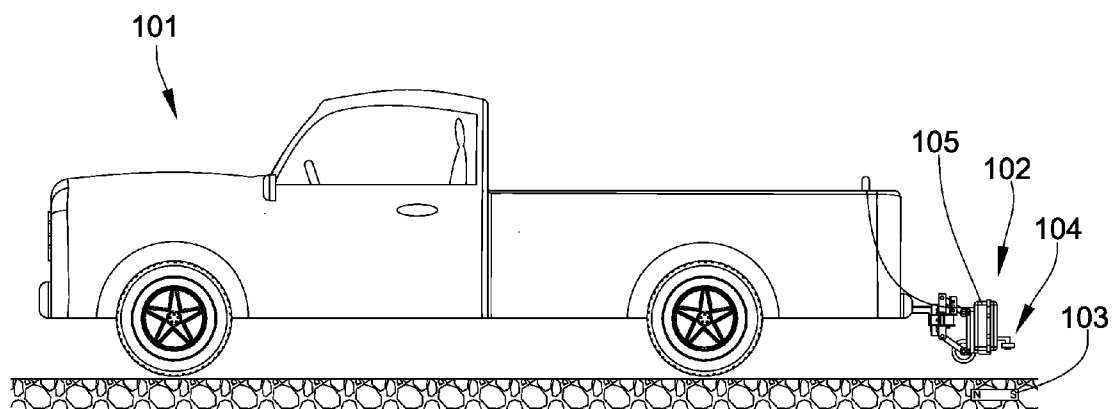
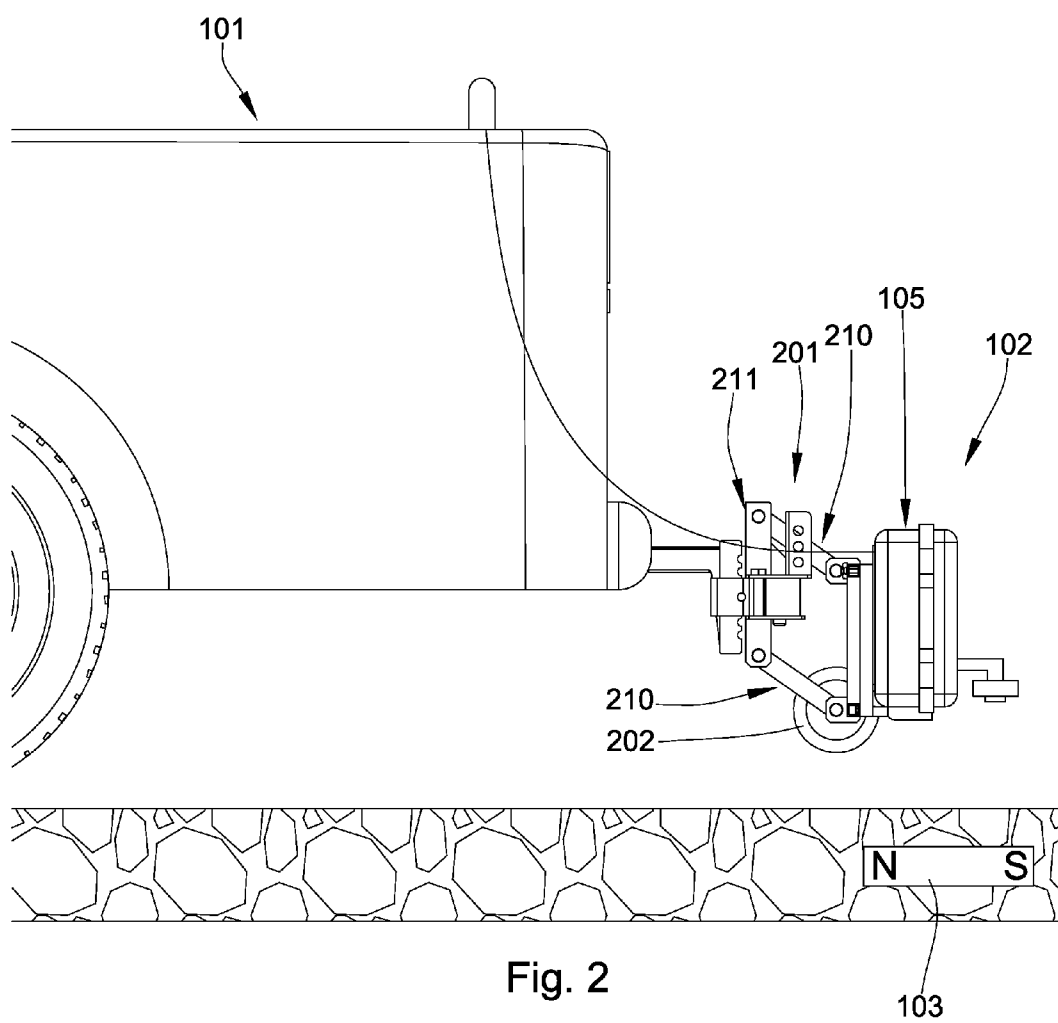


Fig. 1



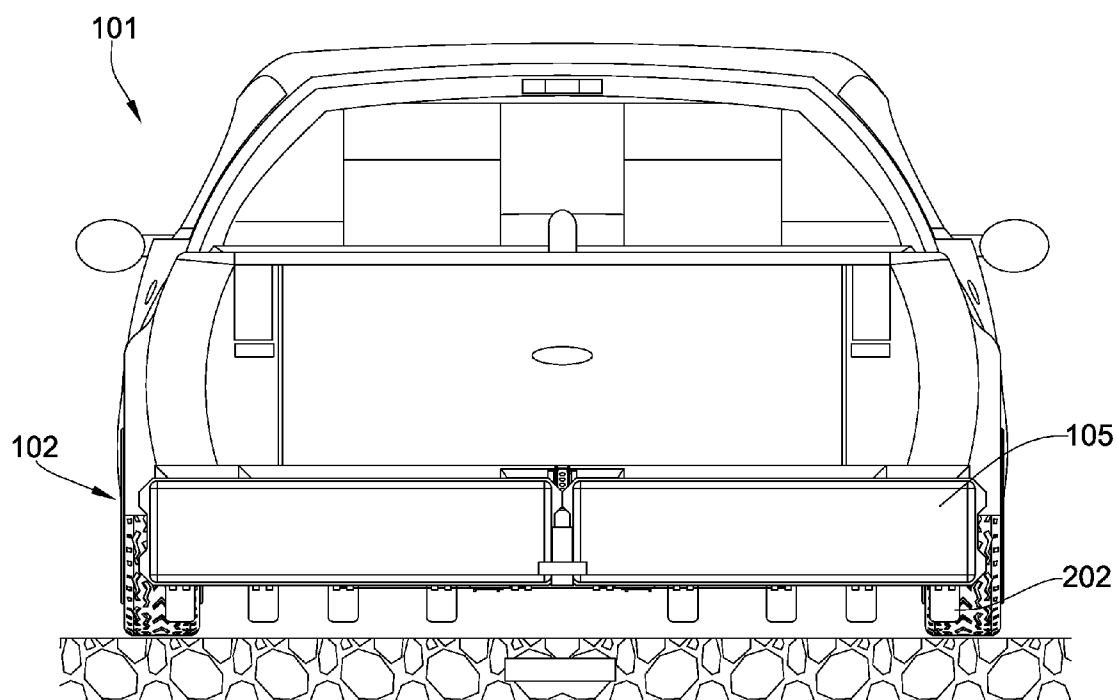


Fig. 3

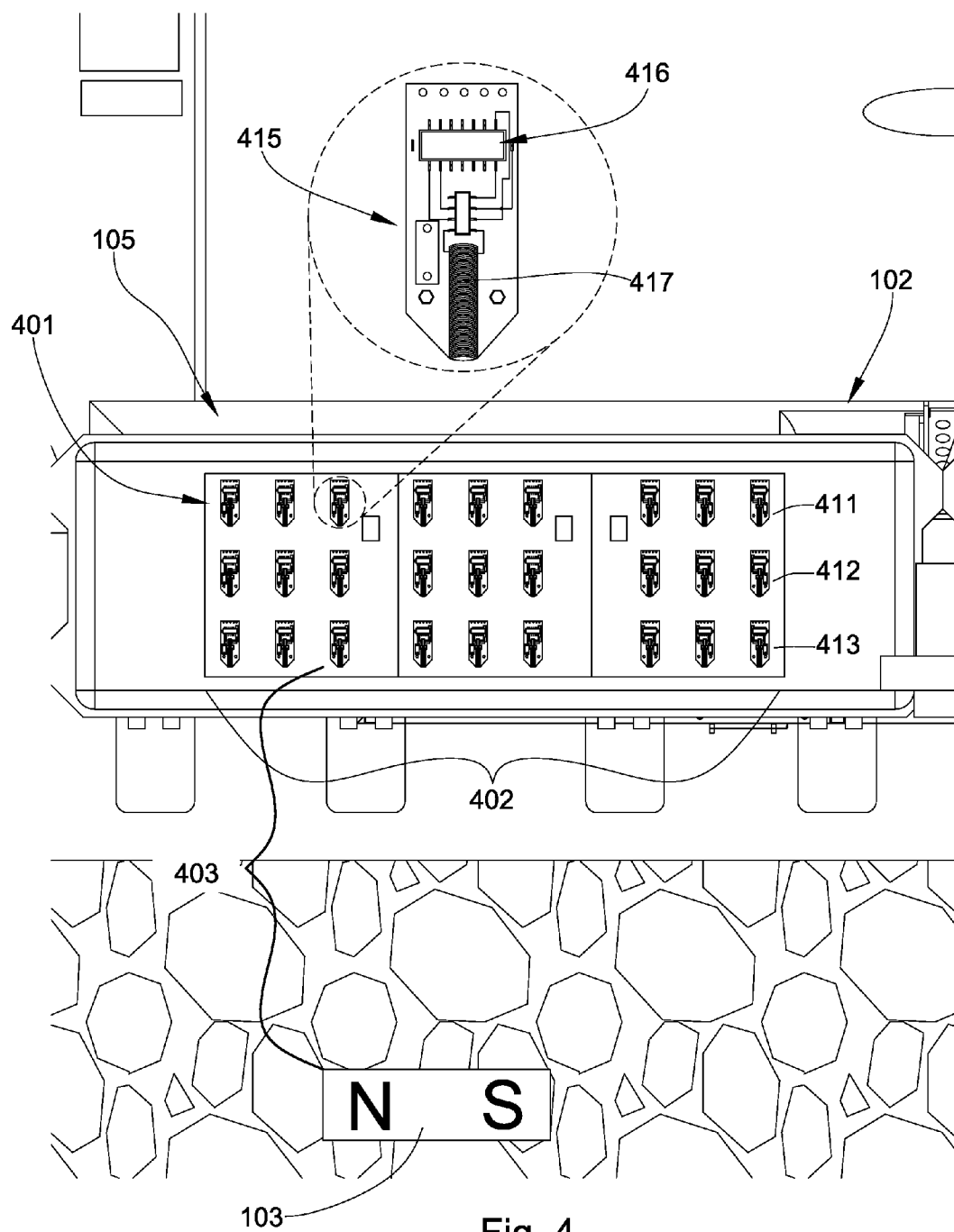


Fig. 4

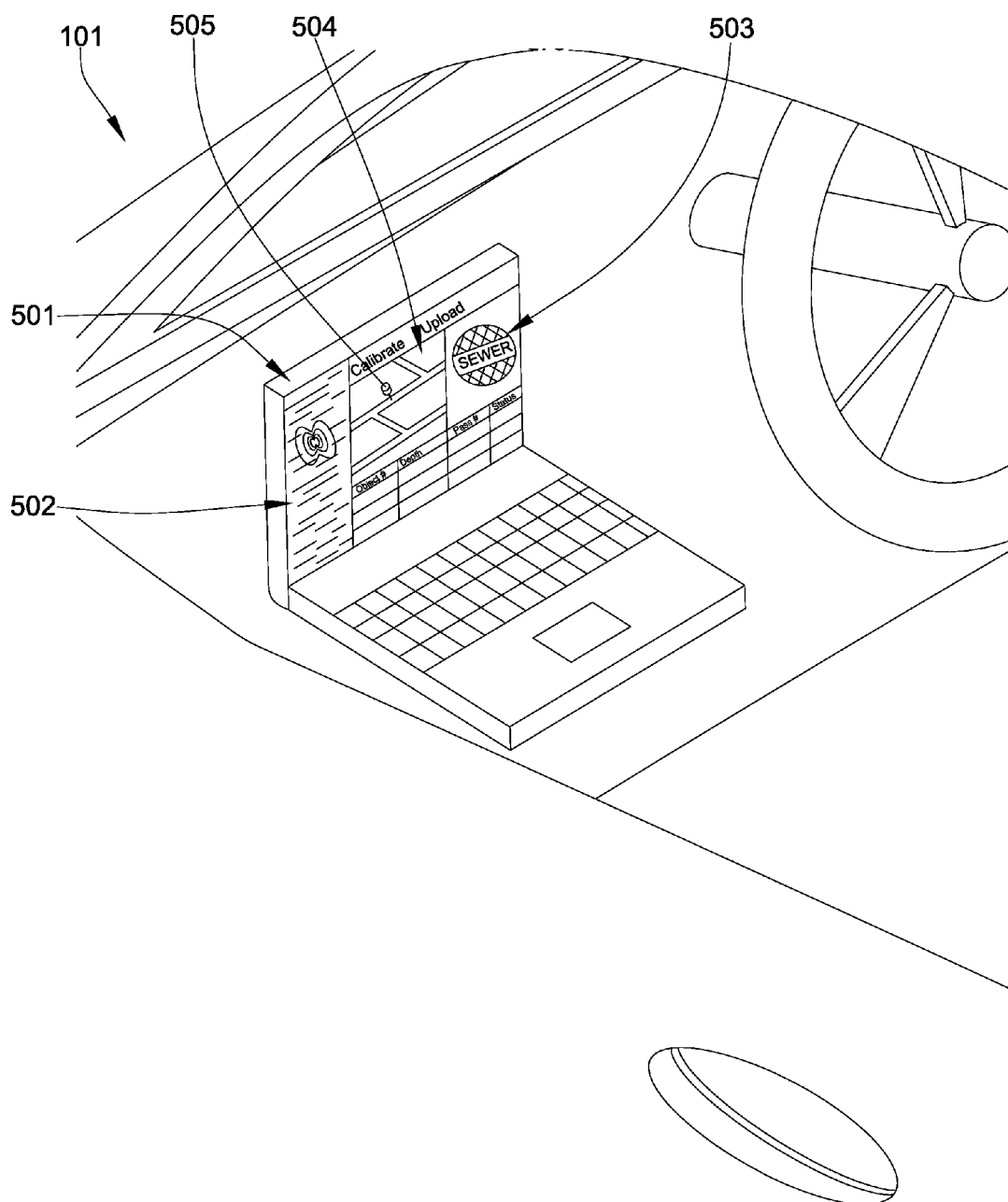
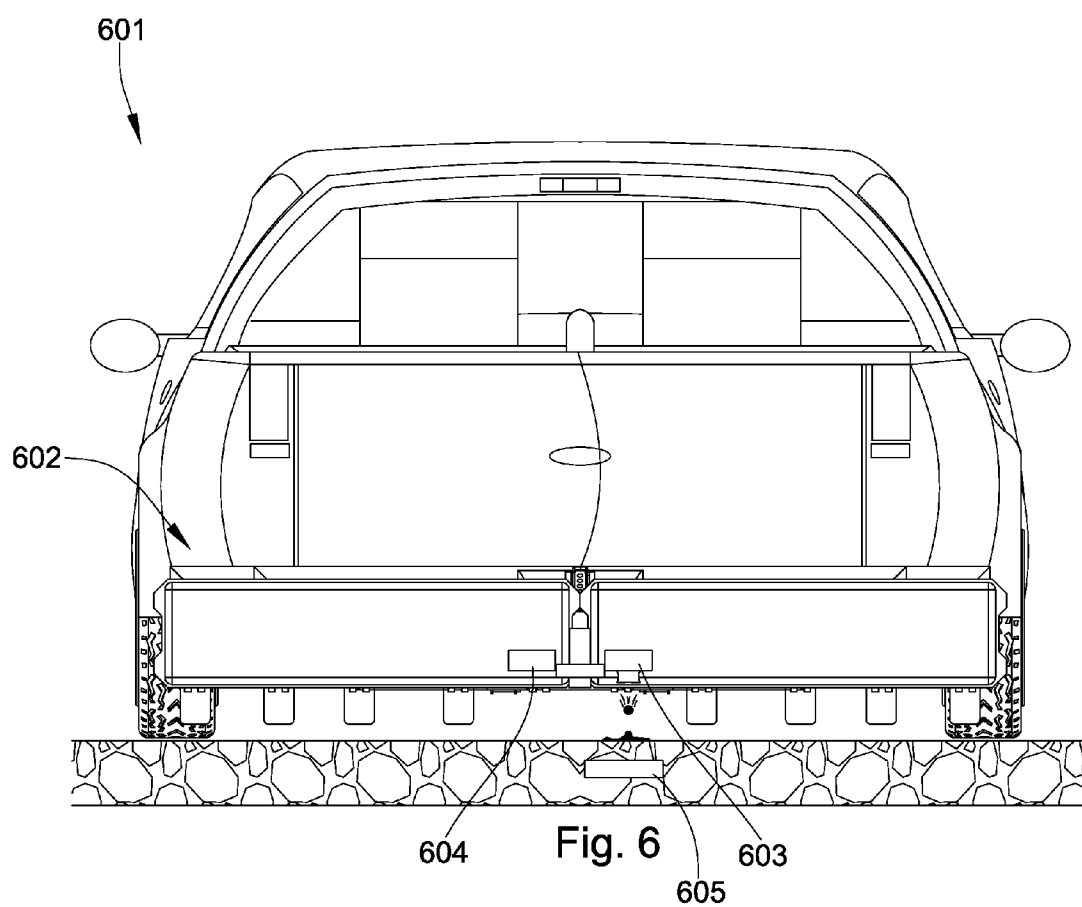


Fig. 5



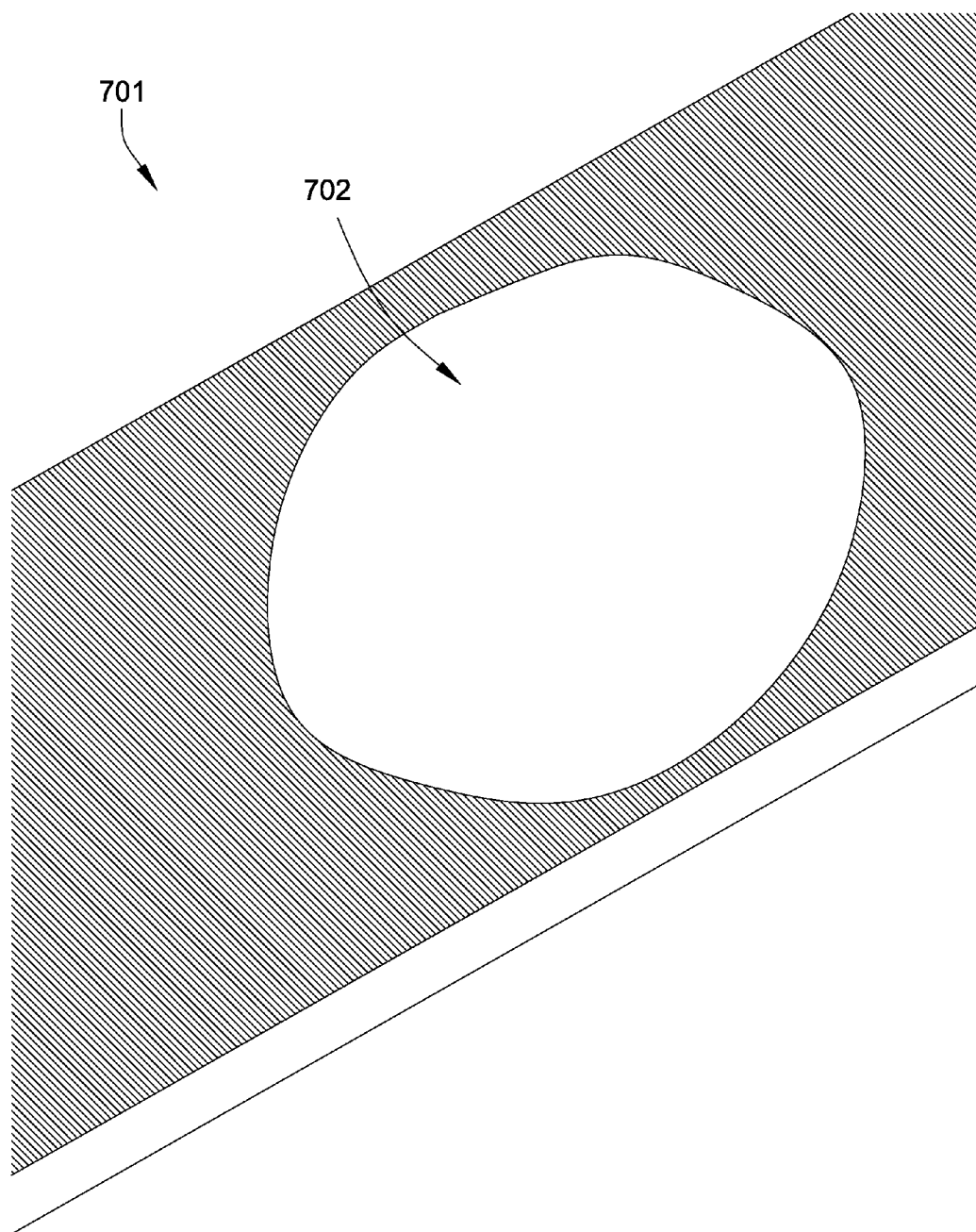


Fig. 7

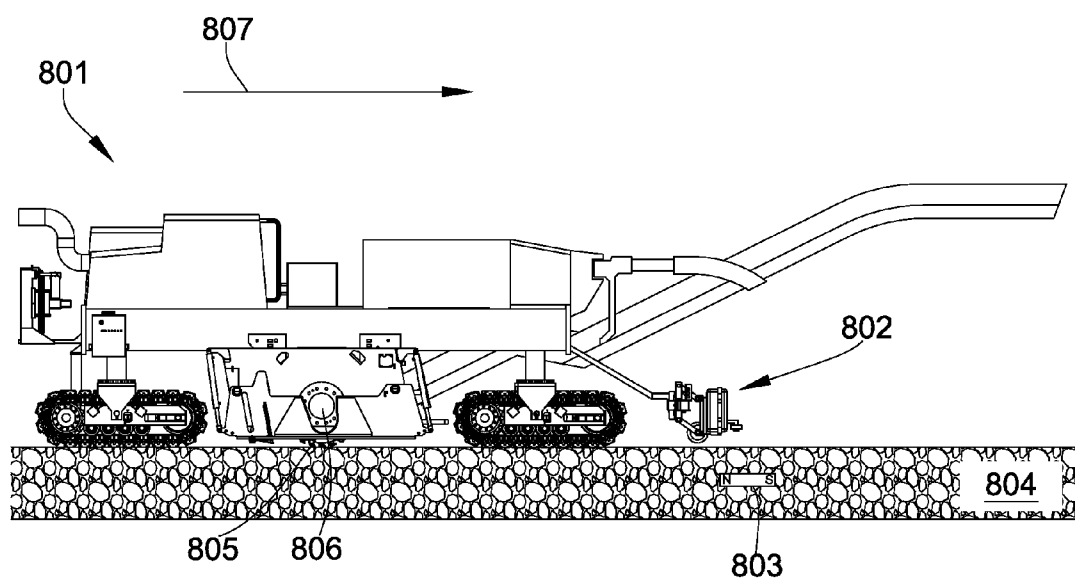


Fig. 8

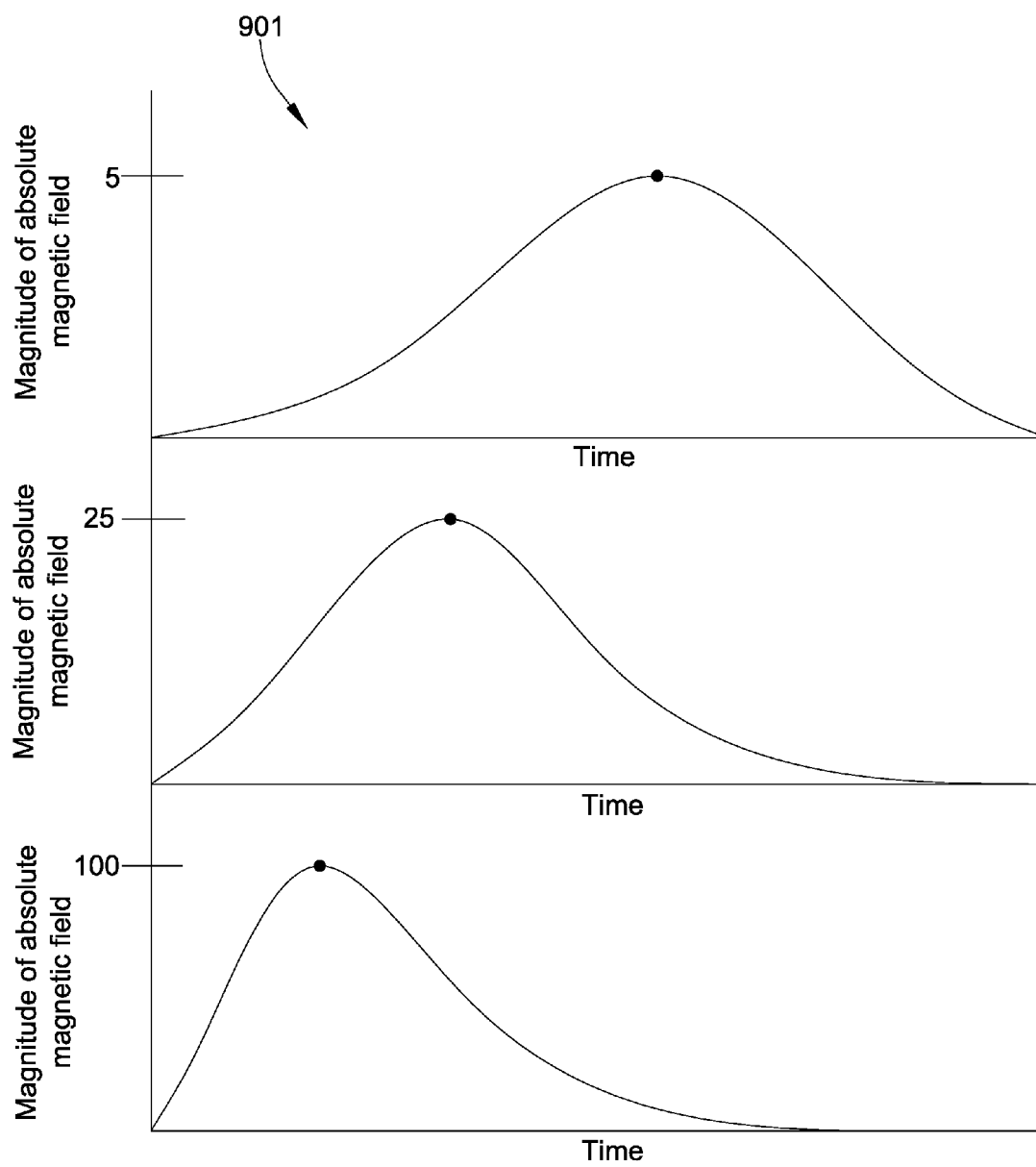


Fig. 9

ASSEMBLY AND METHOD FOR IDENTIFYING A FERROUS MATERIAL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This patent application is a continuation-in-part of U.S. patent application Ser. No. 12/827,525 which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] A road milling machine may comprise a drum populated with a plurality of degradation assemblies, typically picks, which may degrade natural or man-made formations such as pavement, concrete, or asphalt when the drum is rotated while in contact with the man-made formation. It is not uncommon, however, to damage degradation assemblies when they hit hard materials buried underneath or located on the surface of the man-made formations. Such hard materials often comprise ferrous material. The prior art discloses apparatuses and methods for identifying subsurface ferrous materials.

[0003] One such apparatus and method is disclosed in U.S. Pat. No. 5,629,626 to Russell et al., which is herein incorporated by reference for all that it contains. Russell et al. discloses an apparatus and method for collecting magnetometer data at the earth's surface in order to detect anomalies in the earth's magnetic field caused by buried ferromagnetic objects. A plurality of magnetometers are provided in a predetermined array on a mobile platform. A fixed station is also provided on the earth's surface, and navigational data from a global positioning system (GPS) is collected on the location of the fixed station and mobile platform in synchronization with a sync signal received from the GPS. While the mobile platform traverses an area on the earth's surface, magnetometer data is collected in synchronization with the sync signal. The apparatus and method provide a significant improvement in the amount of area which can be surveyed in a given time period and in the precision of the location and magnetic field intensity data collected.

[0004] Another such apparatus and method is disclosed in U.S. Pat. No. 7,372,247 to Giusti et al., which is herein incorporated by reference for all that it contains. Giusti et al. discloses an apparatus and method to locate and mark the surface position of an underground utility while maneuvering along the path of the utility. The apparatus uses an underground utility detector that responds to the location of an underground utility to continually position a carriage proximate vertical of the utility. Marker systems are aligned with the carriage and apply either a unique paint symbol on pavement or a spike in the ground. The apparatus is configured to use an underground utility detector or positioning equipment that generate positional signals. The apparatus may be configured to mark utility positions at predetermined intervals and mark utility offset positions. The apparatus may be attached to a vehicle, towed by a vehicle, motorized or propelled by a person.

BRIEF SUMMARY OF THE INVENTION

[0005] In one aspect of the present invention, a system assembly for identifying a ferrous material comprises a plurality of magnetometers spaced at varying distances from a ferrous material. Each of the plurality of magnetometers may comprise a sensor reading of a magnitude of an absolute

magnetic field, which comprises a magnetic field created by the ferrous material and an ambient magnetic field. One of the plurality of magnetometers may be designated as a primary magnetometer. A distance to the ferrous material from the primary magnetometer may be determined by forming a ratio of the differences in the sensor reading of the primary magnetometer and the sensor readings of the other magnetometers set equal to a ratio of the differences in the distance to the ferrous material from the primary magnetometer inversely cubed and the distances to the ferrous material from the other magnetometers inversely cubed.

[0006] The system assembly may also comprise a picture taking device that may provide an image of a surface viewable from above the ferrous material and a global positioning system device that may provide a map of a geographical region.

[0007] The plurality of magnetometers may comprise at least three vertically spaced magnetometers and may be disposed in a horizontal array. Each magnetometer may provide a sensor reading and the differences in sensor readings of the plurality of magnetometers in the horizontal array may determine the size and shape of the ferrous material.

[0008] The system assembly may also comprise an information processor, an interface, a marking mechanism, a very low frequency metal detector, a pulse induction metal detector, or a ground penetrating radar system. The information processor may be in communication with the plurality of magnetometers, picture taking device and global positioning system device. The information processor may receive a signal from the plurality of magnetometers and then may send a signal to the picture taking device and the global positioning system in response to the received signal. The interface may display a representation of magnetic fields, the image of the surface, and the map of the surface. The marking mechanism may be a paintball gun or a paint sprayer which may apply a marker to the surface viewable from above the ferrous material. The very low frequency metal detector, pulse induction metal detector and ground penetrating radar system may all confirm the signal from the plurality of magnetometers.

[0009] The image from the picture taking device may comprise an infrared image.

[0010] The system assembly may be disposed on a milling machine or a utility vehicle by parallel linkages allowing for vertical movement.

[0011] In another aspect of the present invention a method of identifying a ferrous material comprises providing a plurality of magnetometers, a picture taking device, and a global positioning system device. The global positioning system device may provide a map of a geographical region comprising a ferrous material. The plurality of magnetometers, picture taking device and global positioning system device may pass over the geographical region and a ferrous material may be detected by the plurality of magnetometers. When a ferrous material is detected, an image of the surface viewable from above the ferrous material may be captured with the picture taking device, and a symbol may be positioned on the map at the location of the ferrous material.

[0012] The method of identifying a ferrous material may further comprise determining a distance to the ferrous material from the plurality of magnetometers and inputting an exact location of the plurality of magnetometers and picture taking device into the global positioning system device before passing the plurality of magnetometers, picture taking device, and global positioning system device over the geographical

region. The distance, location, and image of the ferrous material may be uploaded to a database accessible to others not at the location of the ferrous material.

[0013] The step of detecting the ferrous material may comprise obtaining sensor reading from the plurality of magnetometers such that each magnetometer detects a magnetic field of the ferrous material at a different time interval.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a side view of an embodiment of a system assembly disposed on a utility vehicle to identify a ferrous material.

[0015] FIG. 2 is a close-up side view of an embodiment of a system assembly disposed on a utility vehicle to identify a ferrous material.

[0016] FIG. 3 is a back view of a system assembly disposed on a utility vehicle to identify a ferrous material.

[0017] FIG. 4 is a cut-away view of an embodiment of a system assembly to identify a ferrous material.

[0018] FIG. 5 is a perspective view of an embodiment of an interface.

[0019] FIG. 6 is a back view of an embodiment of a marking mechanism disposed on a utility vehicle.

[0020] FIG. 7 is an embodiment of an infrared image of a ferrous material.

[0021] FIG. 8 is an orthogonal view of an embodiment of a road milling machine.

[0022] FIG. 9 is an embodiment of a graph of time vs. magnitude of the magnetic field signal for each magnetometer in a plurality of magnetometers.

DETAILED DESCRIPTION OF THE INVENTION AND THE PREFERRED EMBODIMENT

[0023] Referring now to the figures, FIG. 1 discloses an embodiment of a utility vehicle 101 comprising a system assembly 102 for identifying a ferrous material 103. The system assembly 102 may comprise a plurality of magnetometers, a picture taking device 104, and a global positioning system device. The plurality of magnetometers may be disposed inside a plurality of containers 105. The plurality of magnetometers may identify a ferrous material 103, such as a manhole, which may be buried or disposed on the surface. The picture taking device 104 may provide an image of a surface viewable from above the ferrous material 103. The global positioning system device may provide a map of a geographical region. An information processor may be in communication with the plurality of magnetometers, picture taking device 104, and global positioning system device. The system assembly 102 may pass over the geographical region and the plurality of magnetometers may detect the ferrous material 103. The information processor may receive a signal from the plurality of magnetometers detecting the ferrous material 103. In response to the received signal, the information processor may send a signal to the picture taking device 104 to capture an image and send another signal to the global positioning system device to position a symbol on the map at the location of the ferrous material 103.

[0024] FIG. 2 discloses an embodiment of the system assembly 102 disposed on the utility vehicle 101 by parallel linkages 201. The parallel linkages 201 may comprise a plurality of rigid connections 210 connecting the plurality of containers 105 to a system assembly base 211. The rigid connections 210 may pivot on the system assembly base 211

and allow for vertical movement of the system assembly 102. It is believed that the plurality of containers 105 comprising the plurality of magnetometers needs to be disposed relatively close to the surface of the earth so that the plurality of magnetometers can accurately detect the ferrous material 103.

[0025] The system assembly 102 may also comprise a plurality of wheels 202 to protect the system assembly 102. If the vehicle 101 traverses an uneven surface then the plurality of wheels 202 may keep the plurality of containers 105 from contacting the surface, thus, insulating the system assembly 102 from wear or impact. When the uneven surface comes into contact with the plurality of wheels 202, the uneven surface may raise and lower the system assembly 102.

[0026] In other embodiments, the parallel linkages 201 may physically adjust the vertical position of the plurality of containers 105. The parallel linkages 201 may comprise an electrical mechanism to raise and lower the system assembly 102 to a desired height.

[0027] FIG. 3 discloses an embodiment of the utility vehicle 101 comprising the system assembly 102. This embodiment discloses the system assembly 102 comprising a plurality of containers 105 and a plurality of wheels 202. During normal operations of the system assembly 102, the plurality of magnetometers may be disposed inside the plurality of containers 105. The plurality of containers 105 may protect the plurality of magnetometers from harsh conditions and may comprise electrical connections which may facilitate supplying electricity to the plurality of magnetometers. The system assembly's length may extend the width of the utility vehicle 101 and allow detection along the system assembly's entire length.

[0028] FIG. 4 discloses a cut-away view of an embodiment of the system assembly 102 showing the plurality of magnetometers 401 disposed inside a container of the plurality of containers 105. Also disclosed is a close-up view of a magnetometer 415 of the plurality of magnetometers 401. The magnetometer 415 may be a single coil fluxgate magnetometer comprising circuitry 416 and a coil 417. The circuitry 416 may send a substantially constant current through the coil 417. An absolute magnetic field may provide resistance or assistance to the current. The variation of the current due to the absolute magnetic field may be determined and the magnitude of the absolute magnetic field may be deduced. The absolute magnetic field may comprise the sum of the magnetic field of the ferrous material 103 and an ambient magnetic field. The ambient magnetic field may comprise the sum of the magnetic fields due to the earth and any source except the ferrous material 103.

[0029] The plurality of magnetometers 401 may comprise at least three vertically spaced magnetometers 411, 412, and 413 disposed in a horizontal array 402. It is believed that at least three magnetometers vertically spaced with respect to one another may determine the distance 403 from the plurality of magnetometers 401 to a ferrous material 103. A plurality of horizontal arrays 402 (not shown) may be positioned side by side and/or overlapping each other to allow for maximum detection of ferrous materials.

[0030] One of the at least three vertically spaced magnetometers 411, 412, and 413 may be designated as a primary magnetometer. By way of example only, magnetometer 413 may be designated as the primary magnetometer. Sensor readings for the primary magnetometer 413 and the other magnetometers 411 and 412 may be obtained. A first ratio of the differences in sensor readings of the primary magnetom-

eter 413 to sensor readings of the other magnetometers 411 and 412 may be formed. The first ratio may be set equal to a second ratio of the differences in distance to the ferrous material from the primary magnetometer 413 inversely cubed to distances to the ferrous material from the other magnetometers 411 and 412 inversely cubed. By setting the first ratio equal to the second ratio, the distance 403 to the ferrous material from the plurality of magnetometers 401 may be determined. In the application of the present invention, the distance to the ferrous material 103 is most commonly the depth of the ferrous material 103.

[0031] During typical road milling operations, an operator may set the depth of penetration of the degradation assemblies of a milling machine. If the depth of the ferrous material is found to be deeper than the depth of penetration of the degradation assemblies then no action need be taken.

[0032] As the plurality of magnetometers 401 pass over the geographical region and individually detect the ferrous material 103, differences in sensor readings of variously spaced magnetometers of the plurality of magnetometers 401 may indicate the size and shape of the ferrous material 103. Knowing the size and shape of the ferrous material 103 may facilitate in choosing an appropriate course of action for dealing with the ferrous material 103.

[0033] In some embodiments, vertical spacing of the plurality of magnetometers 401 may not be required if determining the distance to the ferrous material 103 is unnecessary.

[0034] FIG. 5 discloses an embodiment of a user interface 501 disposed inside the utility vehicle 101. In some embodiments, the user interface is wireless and located remotely from the vehicle. The interface 501 may display a representation of magnetic fields 502, the image of the surface 503, and the map of the surface 504. The representation of magnetic fields 502 may be produced by the plurality of magnetometers and may display anomalies in the magnetic fields. The anomalies may indicate a magnetic field of a ferrous material. The plurality of magnetometers may send a signal to an information processor when a ferrous material is detected. The information processor may then send a signal to the picture taking device to capture an image of the surface 503 and send another signal to the global positioning system device to position a symbol 505 on the map of the surface 504.

[0035] The picture taking device may capture an image of the surface viewable from above the ferrous material which may visually confirm the signal from the plurality of magnetometers. If no object is visible from the image, then a ferrous material may be buried beneath the formation and the location may be physically marked for later identification.

[0036] Before passing the system assembly over the geographical region, the global positioning system may need to be calibrated by inputting the exact location of the system assembly. For example, the exact location of a building or landmark may be inputted into the global positioning system device to adjust the reading of the global positioning system device to correspond with the exact location of the system assembly.

[0037] After determining a ferrous material's depth and location, the information processor may upload the depth, location, and image to a database that is remotely accessible. The database may be accessible to any construction or operations worker contracted to work the area with the ferrous material. Also, government employees may also access the database for determining repairs and long term planning. Also,

a centralized manager may communicate to crews working locally about the magnetic material.

[0038] FIG. 6 discloses an embodiment of a utility vehicle 601 comprising a system assembly 602 comprising a marking mechanism 603 and a backup detecting mechanism 604. The marking mechanism 603 may be a paintball gun or a paint sprayer that marks where ferrous material 605 is buried. The backup detecting mechanism 604 may be a very low frequency metal detector, a pulse induction metal detector, or a ground penetrating radar system. The backup detecting mechanism 604 may confirm a signal from the plurality of magnetometers and may confirm the depth of the ferrous material. The information processor may receive a signal from the plurality of magnetometers when ferrous material is detected. Upon receiving the signal, the information processor may send another signal to mark the location and another signal to the backup detecting mechanism 604 to confirm the ferrous material's presence and depth.

[0039] FIG. 7 discloses an embodiment of an infrared image 701 that may be provided by the picture taking device. The picture taking device may provide an image of the surface viewable from above a ferrous material 702. Because the ferrous material 702 may be disposed on the surface or be buried, the picture taking device may provide an image of the ferrous material or of the ground. It is believed that the infrared image 701 may detect differences in energy absorption on a surface. Because a ferrous material absorbs energy at a different rate than the surrounding ground, the infrared image may verify the ferrous material's presence regardless whether the ferrous material is buried.

[0040] FIG. 8 discloses an embodiment of a milling machine 801 comprising a system assembly 802 for identifying a ferrous material 803. The milling machine 801 may be a planer used to degrade man-made formations 804 such as pavement, concrete or asphalt prior to placement of a new layer of pavement. The milling machine 801 may comprise a plurality of degradation assemblies 805 attached to a driving mechanism 806. During normal milling operations, the degradation assemblies 805 may come into contact with a ferrous material 803 and damage the degradation assemblies 805. The system assembly 802 may alert an operator of the milling machine 801 of the ferrous material 803.

[0041] FIG. 9 discloses an embodiment of a graph 901 of time vs. magnitude of the absolute magnetic field for various magnetometers in a plurality of magnetometers. This embodiment comprises the time vs. magnitude of the absolute magnetic field for three vertically spaced magnetometers. This embodiment discloses that each magnetometer of the plurality of magnetometers may detect the greatest magnitude of the absolute magnetic field at a different time interval. It is believed that detecting the greatest magnitude of the absolute magnetic field at different time intervals may facilitate calculating the distance to the ferrous material from the plurality of magnetometers. The sensor readings comprising the magnitude of the absolute magnetic field may be processed individually due to the obtaining the sensor readings at different time intervals instead or processing multiple sensor readings at a time. It is believed that by processing the sensor readings individually the sensor readings may be read more accurately.

[0042] Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications apart from

those shown or suggested herein, may be made within the scope and spirit of the present invention.

What is claimed is:

1. A system assembly for identifying a ferrous material comprising:

a plurality of magnetometers spaced at varying distances from a ferrous material each comprising a sensor reading of a magnitude of an absolute magnetic field;

wherein one of the plurality of magnetometers is designated as a primary magnetometer and a distance to the ferrous material from the primary magnetometer is given by a ratio of the differences in the sensor reading of the primary magnetometer and the sensor readings of the other magnetometers set equal to a ratio of the differences in the distance to the ferrous material from the primary magnetometer inversely cubed and the distances to the ferrous material from the other magnetometers inversely cubed;

a picture taking device providing an image of a surface viewable from above the ferrous material; and

a global positioning system device providing a map of a geographical region.

2. The system assembly of claim 1, wherein the plurality of magnetometers comprises at least three vertically spaced magnetometers.

3. The system assembly of claim 1, wherein the plurality of magnetometers comprises a horizontal array of magnetometers.

4. The system assembly of claim 3, wherein the differences in sensor readings of the horizontal array of magnetometers determines the size of the ferrous material.

5. The system assembly of claim 3, wherein the differences in sensor readings of the horizontal array of magnetometers determines the shape of the ferrous material.

6. The system assembly of claim 1, further comprising an information processor in communication with the plurality of magnetometers, picture taking device and global positioning system device wherein the information processor receives a signal from the plurality of magnetometers and sends a signal to the picture taking device and the global positioning system device.

7. The system assembly of claim 1, further comprising an interface wherein the interface displays a representation of magnetic fields, the image of the surface, and the map of the surface.

8. The system assembly of claim 1, further comprising a marking mechanism to apply a marker to the surface viewable from above the ferrous material.

9. The system assembly of claim 8, wherein the marking mechanism is a paintball gun or a paint sprayer.

10. The system assembly of claim 1, wherein the image comprises an infrared image.

11. The system assembly of claim 1, further comprising a very low frequency metal detector to confirm a signal from the plurality of magnetometers.

12. The system assembly of claim 1, further comprising a pulse induction metal detector to confirm a signal from the plurality of magnetometers.

13. The system assembly of claim 1, further comprising a ground penetrating radar system to confirm a signal from the plurality of magnetometers.

14. The system assembly of claim 1, wherein the assembly is disposed on a milling machine or utility vehicle by parallel linkages allowing for vertical movement.

15. A method for identifying a ferrous material, comprising:

providing a plurality of magnetometers, a picture taking device, and a global positioning system device wherein the global positioning system device provides a map of a geographical region comprising a ferrous material;

passing the plurality of magnetometers, picture taking device and global positioning system device over the geographical region;

detecting the ferrous material from the plurality of magnetometers;

capturing an image with the picture taking device of a surface viewable from above the ferrous material; and positioning a symbol on the map at a location of the ferrous material.

16. The method of claim 15, further comprising providing an information processor and receiving a signal with the information processor from the plurality of magnetometers and sending with the information processor a signal to a picture taking device to capture an image and global positioning system device to position a symbol on the map in response to the received signal.

17. The method of claim 15, further comprising determining a distance to the ferrous material from the plurality of magnetometers.

18. The method of claim 17, further comprising uploading the distance, location, and image of the ferrous material to a database.

19. The method of claim 15, wherein detecting the ferrous material comprises obtaining sensor readings from the plurality of magnetometers such that each magnetometer detects a magnetic field of the ferrous material at a different time interval.

20. The method of claim 15, further comprising inputting an exact location of the plurality of magnetometers and picture taking device into the global positioning system device before passing the plurality of magnetometers, picture taking device and global positioning system device over the geographical region.

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