United States Patent [19]

Fayling

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[45] **Jan. 30, 1973**

[54] **VEHICLE GUIDANCE TRACK OF TRANSVERSE EXTENT**

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[22] Filed: **March 30, 1971**

[21] Appl. No.: **129,521**

[52] **U.S. Cl.**.....**340/32,** 94/1.5 R, 180/98

[51] **Int. Cl.**.....**G08g 1/09,** E01f 11/00

[58] **Field of Search**.....340/31 R, 31 A, 32, 33, 38 R, 340/38 L; 180/97, 98, 103; 29/307; 94/1.5 R

[56] **References Cited**

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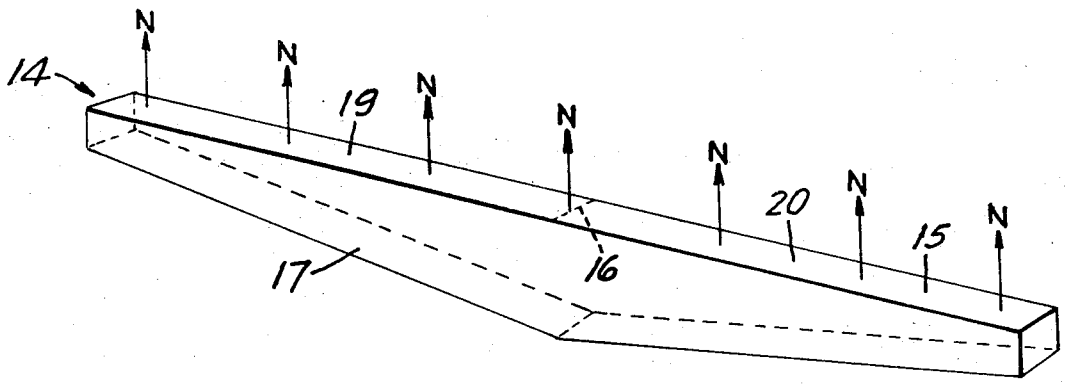
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[57] **ABSTRACT**

A vehicle guidance track comprising a plurality of magnet installations aligned in spaced relation on the longitudinal axis of the track and extending in a direction transverse to the longitudinal axis. The magnet installations change, and correspondingly the magnetic fields of the installations change, over the transverse extent of the installation. Thus, flux sensors in vehicles traveling over the track generate signals that indicate the transverse location of the vehicles on the track.

12 Claims, 9 Drawing Figures



Patented Jan. 30, 1973 **3,714,625**

3 Sheets-Sheet 1

FIG. 1

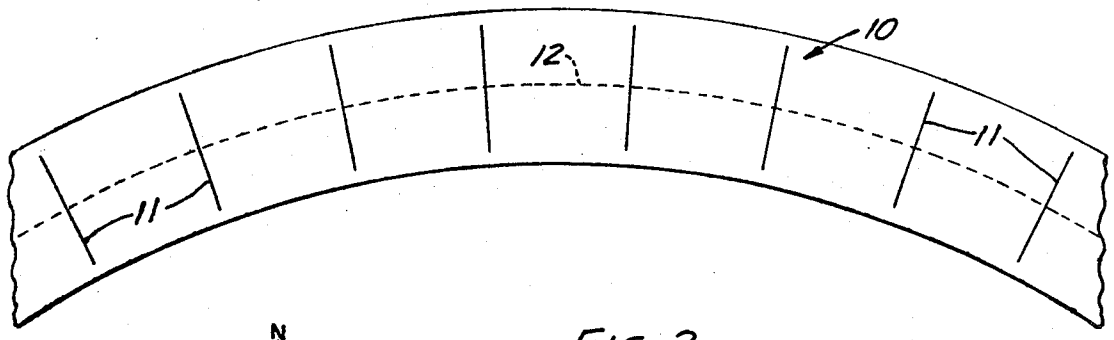


FIG. 2

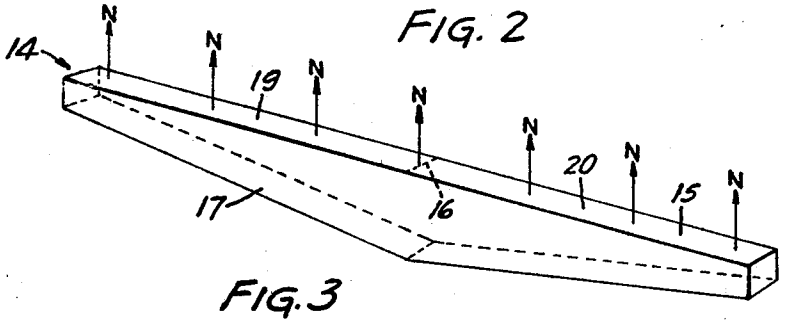


FIG. 3

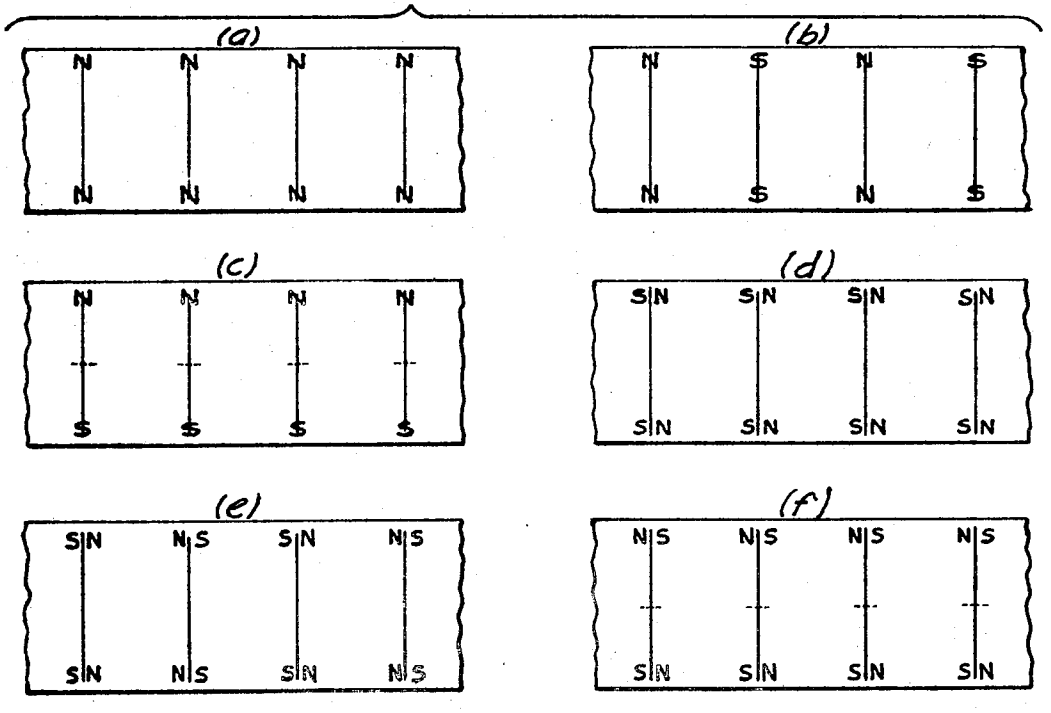
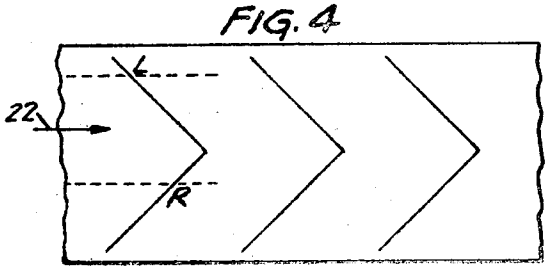


FIG. 4



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FIG. 5

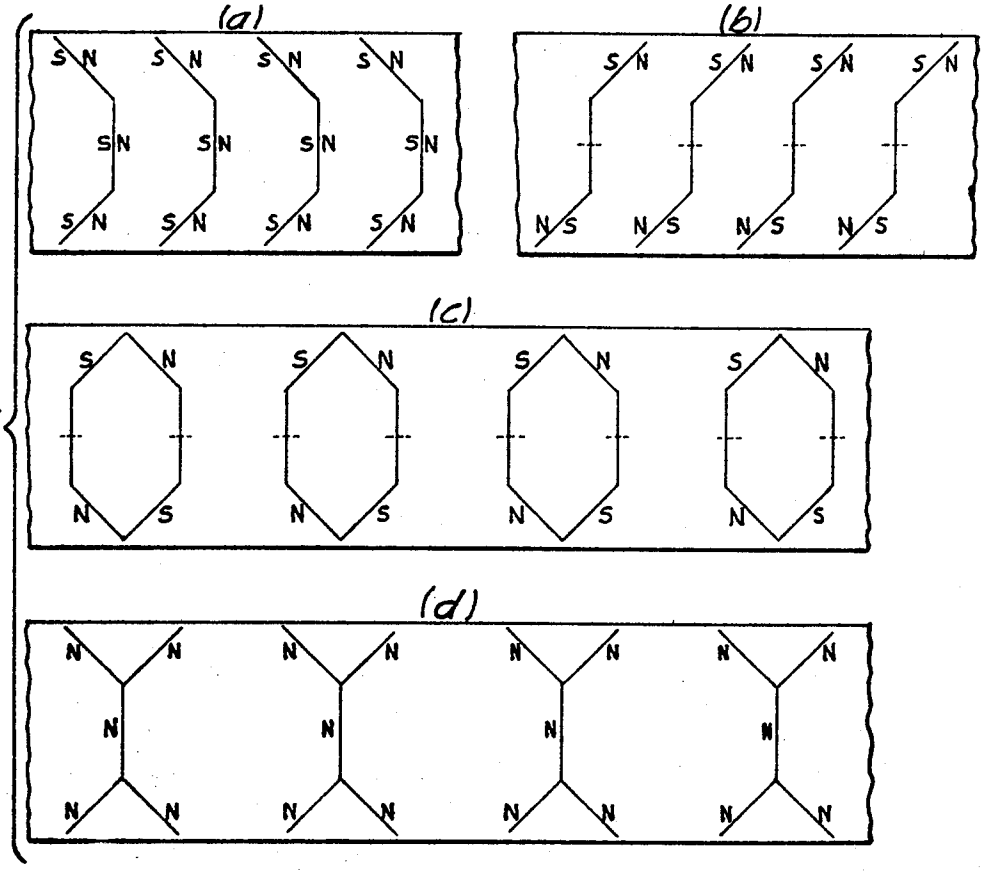
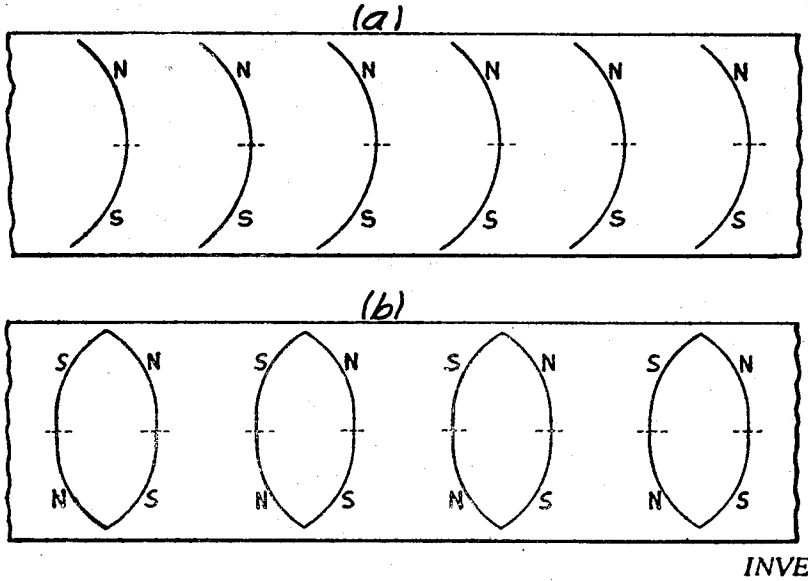


FIG. 6



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FIG. 7

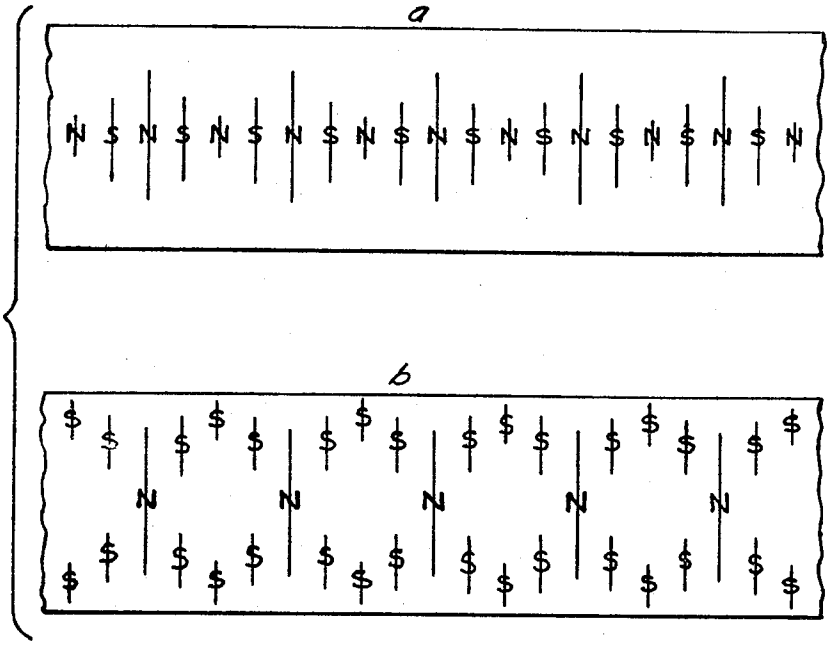


FIG. 8

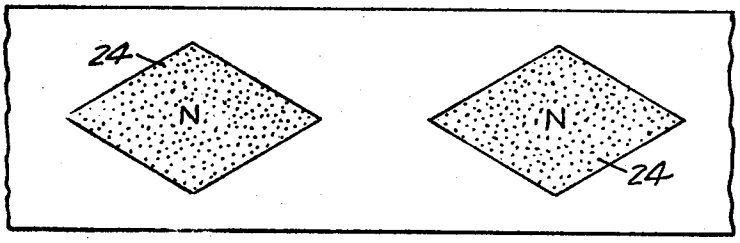
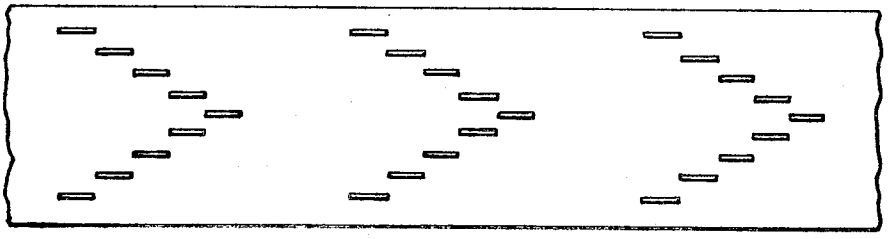


FIG. 9



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VEHICLE GUIDANCE TRACK OF TRANSVERSE EXTENT

Courses or tracks of magnet installations extending longitudinally along a roadway offer a fail-safe source, not requiring electric power, of control and guidance information for vehicles traveling on the roadway. For example, in one typical form such a track produces a magnetic field that comprises a series of alternate north and south magnetic poles extending along the roadway. An alternating electric signal is developed in a flux sensor on a vehicle traveling over the track, with the frequency of the signal representing the speed of the vehicle.

The present invention makes a basic change in magnetic-vehicle guidance tracks to give the tracks an important additional utility. More specifically, the present invention conceives of a need for guidance information a long distance from the center of a magnetic vehicle guidance track and provides a track that will make available such information. In the past it has been proposed to steer vehicles by using the reduction in signal that occurs in a flux sensor when a vehicle deviates from a magnetic vehicle guidance track. With previously suggested magnetic tracks, however, this system for steering is practical only on narrow roadways, as for automobiles traveling in a single lane of a street or highway, since the useful magnetic field does not extend more than a few feet from the track. There are important situations in which such a steering system is not useful—for example, for airplanes traveling on a runway, waiting apron, or taxi-way, or smaller vehicles traveling over a wide roadway such as an automobile parking lot, collection area for powered carts in a factory, etc.

The present invention makes possible automatic steering and the provision of guidance information in the latter kind of situation. Briefly, the present invention provides extensive transverse guidance information with magnet installations that individually extend transversely to the direction of travel of a vehicle over the track. These magnet installations are characterized in that they change, and correspondingly the magnetic field provided by the installations change, in a predetermined manner over the transverse extent of the installations. Stated in another way, the parts of the magnet installations located at at least two different distances from the longitudinal axis of the roadway contribute different vector components of magnetic field, these vector components being at a sensing line that is transverse to the longitudinal axis and parallel to the surface of the roadway (vector components of a magnetic field indicate the direction and magnitude of the magnetic field on the x, y, and z axes at the point of measurement). Preferably, the changes in magnetic field is provided by a change in the geometric configuration of the installation—e.g., a change in size, shape, longitudinal dimensions, etc.—over its transverse extent. For example, the installation may be line shaped, and the longitudinal positions of at least some points along the line differ over the transverse extent of the installation. Or cross-sectional dimensions may change over the transverse extent of the magnet installation.

Magnet installations of a track of the invention are aligned in spaced relation along a longitudinal axis of the track and usually are centered on the longitudinal axis. The longitudinal spacing between the installations is chosen to provide the desired number and pattern of signal pulses and, when the spacing is regular, provides a basis for indicating the speed of vehicles traveling on the trjck as a function of the frequency of the pulsating electric signal developed in flux sensors in the vehicles. The transverse-extending installations of the invention may be only part of a complete track, with additional magnet installations between the transverse-extending installations to, for example, provide speed measurement, provide location codes, or trigger a particular function within a vehicle. And one or more vehicle guidance tracks may lie alongside one another, as where separate tracks are used for separate lanes of a roadway. By use of appropriate circuitry in a vehicle, the vehicle may continuously receive information as to its transverse location when it changes from one track to another. Further, tracks may be partially superimposed over one another, as where one track coincides with another track over part of its length.

The magnet installations preferably comprise permanent magnets (as opposed to electromagnets), which increase the reliability of the system because they do not require external energy sources that could fail. Further, the permanent magnets are preferably polymer-based magnets, which comprise a tough organic polymeric matrix and particles of magnetic materials such as barium ferrite uniformly distributed through the matrix. Polymer-based magnet materials offer several advantages for use on roadways of the invention. They may be made in strip or tape form so that one integral piece will extend across as great a width of the roadway as desired; they are adapted to convenient and inexpensive installation; and they are highly resistant to fracture or other deterioration under the stresses that occur within roadways as a result of traffic on the roadways and daily and seasonal temperature variations.

A preferred polymer-based magnet producing high magnetic force is described in several patents of Blume, including U.S. Pat. Nos. 2,999,275 and 3,359,152. As taught in those patents, substantially domain-size anisotropic magnetic particles are oriented during the process of manufacture, placing their preferred magnetic axes in substantially parallel alignment so that the magnet is itself anisotropic.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top schematic view of a vehicle guidance track and roadway of the invention;

FIG. **2** is a perspective view of a magnet strip useful as a magnet installation of the invention; and

FIGS. **3–9** are top schematic views of different vehicle guidance tracks of the invention.

DETAILED DESCRIPTION

The illustrative track **10** of the invention shown in FIG. **1** comprises a set of magnet installations that each comprise a straight-line polymer-based magnet strip **11**, the strips having their center points aligned on and spaced along a curved longitudinal axis **12**. The magnet strips **11**, which may be adhered to the surface of the roadway or installed in a channel at or near the surface of the roadway, change in a predetermined manner over their transverse extent. FIG. **2** is a perspective view showing how one kind of straight-line magnet strip

varies. The magnet strip **14** is magnetized vertically (vertically with respect to the roadway after the magnet strip is in place in the roadway), and the top face **15** of the magnet strip presents a north pole. The height of the magnet strip is greatest at its center point **16**, causing the strength of the magnetic field provided by the magnet strip **14** to gradually decrease in magnitude at points more remote from the center point. For typical commercial polymer-based magnet material (such as "-Plastiform 1" Brand polymer-based magnet material), the strength of the vertical component of a magnetic field, B, a distance *h* directly above any point along the magnet strip **14** shown in FIG. **2** is approximately given by the formula,

$$B = 320 \frac{(L)(V)}{h^2 + \frac{L^2}{4}} \text{ gauss},$$

where L is the longitudinal dimension of the strip on the roadway (i.e. the thickness of the strip), V is its vertical dimension, and the transverse dimension of the strip is large compared to *h*.

Useful straight-line magnet strips of the invention may also have their lowest height at the center and gradually increase in height at distances more remote from the center. And the magnet strip may be magnetized with the direction of magnetization horizontal (parallel to the top face **15** of the magnet strip **14**), so that a north pole is presented on one face of the magnet strip (e.g., the face **17** of the magnet strip **14**) and a south pole presented on the opposite face. In that case the horizontal component of a magnet field B, a distance *h* directly above the described commercial polymer-based magnet is approximately given by the formula

$$B = 320\,(L)\,(V)/[h\,(h+L)]\text{gauss},$$

where L and V have the designations given above, and the transverse dimension of the strip is large compared to *h*.

Also, the magnet strip may comprise parts of different magnetization, so that, for example, one side **19** of the magnet strip might present a north pole at the top face, and the other side **20** present a south pole at the top face. A different way to vary the magnetic field of a straight-line magnet strip over its transverse extent is to change the remanent magnetization over the transve9se extent of the strip. Or the orientation of the magnetization of the strip can be gradually changed.

FIG. **3** shows a variety of useful tracks of straight-line magnet strips. In FIG. **3**(a), a magnet strip such as shown in FIG. **2** is used in which the whole top face of each magnet strip presents a north pole (when N or S appear alone on or adjacent a line in the drawing as in FIG. **3**(a) or **5**(c), they represent vertical magnetization; when used together on opposite sides of the line as in FIG. **3**(d) they represent horizontal magnetization). With a track of FIG. **3**(a) the signal developed in a flux-sensor traveling over the track will be identical in both directions of travel. Such a track is described herein as having bi-directional symmetry. This property is exhibited by a track which would appear identical before and after rotation 180° about a vertical axis through the center of the track. Such a symmetry is often preferred, so that an identical signal will be developed in a flux-sensor irrespective of which direction the sensor is traveling longitudinally along the track. The track shown in FIG. **3**(b) also exhibits bidirectional symmetry, since a portion of track properly chosen would appear identical after rotation **180°** as described.

The track shown in FIG. **3**(c) (comprised of magnet strips having two parts of opposite vertical magnetization joined at the dotted line) does not exhibit bi-directional symmetry, and the signal generated in a flux-sensor traveling over the track will differ depending on which of the two directions the flux-sensor is traveling. By choosing appropriate circuitry connected to flux-sensors in the vehicle, the signals can provide the same information irrespective of the direction traveled. But the difference in signal may be useful to automatically provide information as to the direction the vehicle is traveling. Also, when vehicles travel on different sides of the center of the track, the track shown in FIG. **3** (c) will provide a signal of one polarity to vehicles on one side of the track and a signal of opposite polarity on the other side of the track. In FIGS. **3**(d), (e), and (f) the direction of magnetization is horizontal, or parallel to the top face of the magnet strip; the track of FIG. **3**(d) is not bi-directionally symmetrical, though the only difference from bi-directional symmetry is that the polarity of the signal developed is reversed by different directions of travel; the tracks of FIGS. **3**(e) and (f) are bi-directionally symmetrical.

FIG. **4** shows a different type of track of the invention comprised of straight-line magnet strips. In this track, each magnet installation comprises two straight-line magnet strips joined at an angle, with the apex of the angle the center of the installation and located on the longitudinal axis of the track. As a vehicle having two or more flux-sensors mounted on an axis transverse to the direction of travel of the vehicle (which may be defined as a sensing line transverse to the longitudinal axis of the roadway and parallel to the surface of the roadway) moves over the track, signals will be developed in the sensors that indicate the transverse location of the vehicle by virtue of the order and timing of the signals. Thus, as illustrated in FIG. **4**, the left flux-sensor of a vehicle moving in the direction of the arrow will pass over a magnet strip at the point L earlier than the right flux-sensor, if the vehicle is to the left of center on the track. The track shown in FIG. **4** does not exhibit bi-directional symmetry, though by choosing appropriate circuitry in the sensing apparatus within the vehicle, the track may be used irrespective of the direction the vehicle is traveling.

FIG. **5** shows a variety of tracks of the invention in which the magnet-installations comprise straight-line magnet strips set at angles to one another and to the direction of travel of the vehicles on the track. These tracks define a center part of the track for which no corrective signal is provided. Only excessive deviations cause a flux-sensor on one side of a vehicle to produce a signal before a flux-sensor on the other side. Of the tracks shown in FIG. **5**, only the track of FIG. **5**(a) does not exhibit bi-directional symmetry.

The tracks shown in FIG. **6** use curved line-shaped magnets, and therefore may be designed to provide more detailed information as to the transverse location of a vehicle, since the time spacing between signals developed in two flux-sensors spaced along the trans-

verse axis of a vehicle will increase the further the vehicle deviates from center.

FIG. 7 illustrates a different kind of track of the invention. In this embodiment, a set of straight-line magnet strips comprises one magnet-installation. As a vehicle deviates from center, the signals developed in flux-sensors on different sides of a vehicle may change in frequency, waveform, or sometimes magnitude to measure the amount of the deviation. In FIG. 8, magnet installations 24 are comprised of solid flat sheets of polymer-based magnet.

Instead of using straight-line polymer-based magnet strips or sheets of polymer-based magnet material, sets of individual magnets such as alnico or ceramic magnets may be used to form a magnet installation of the invention, as illustrated in FIG. 9. Such magnet installations have the disadvantage that they are more difficult to install and are not as well adapted to undergoing stresses that occur within a pavement. The individual magnets in the track of FIG. 9 may have vertical or horizontal magnetization, as in FIGS. 3(a) and 3(d), respectively, and the track is related in form and function to the track shown in FIG. 4. Magnetizable paints, such as taught in Wickstrom, U.S. Pat. No. 3,575,255, may also be used to provide magnet installations of the invention.

The invention is principally used in tracks of longitudinally spaced magnet installations. But a single transverse-extending magnet installation whose magnetic field varies over its transverse extent is also useful, to indicate the location of a vehicle at the threshold of a collection area, for example.

I claim:

1. A vehicle guidance track on a roadway comprising a set of magnet installations aligned in spaced relation on a longitudinal axis of the roadway, characterized in that at least a plurality of the magnet installations individually extend in a direction transverse to the longitudinal axis and change in a predetermined manner over at least part of their transverse extent such that the parts of said transversely extending magnet installations located at a first distance from said longitudinal axis contribute a first set of vector components of magnetic field as measured at a sensing line that is transverse to the longitudinal axis and parallel to the surface of the roadway, and the parts of said magnet installations located at at least one different distance from said longitudinal axis contribute a second set of vector components of magnetic field at said sensing line, the second set of vector components being different from the first set of vector components, whereby electric signals are generated in flux-sensors in vehicles traveling over the track that indicate the transverse location of the vehicles on the track.

2. A track of claim 1 in which said plurality of magnet installations comprise polymer-based magnets.

3. A track of claim 1 in which the change in said plurality of magnet installations is a change in geometric configuration.

4. A track of claim 1 in which at least part of at least one magnet installation has a straight-line shape and extends at an angle of less than 90° to the longitudinal axis of the track.

5. A track of claim 1 in which at least one magnet installation comprises two straight-line-shaped parts joined together at an angle, with the apex of the angle located at the longitudinal axis of the track.

6. A track of claim 1 in which at least part of at least one magnet installation has a curved-line shape.

7. A track of claim 3 in which at least one of said plurality of magnet installations comprises a polymer-based magnet and the change in geometric configuration is provided by changing the cross-sectional size of the magnet over its transverse extent.

8. A magnet installation on a roadway comprising at least one polymer-based magnet, the magnet installation extending in a direction transverse to the longitudinal axis of the roadway and changing in a predetermined manner over at least part of its transverse extent such that the parts of said transversely extending magnet installation located at a first distance from said longitudinal axis contribute a first set of vector components of magnetic field as measured at a sensing line that is transverse to the longitudinal axis and parallel to the surface of the roadway, and the parts of said magnet installation located at at least one different distance from said longitudinal axis contribute a second set of vector components of magnetic field at said sensing line, the second set of vector components being different from the first set of vector components, whereby electric signals are generated in flux-sensors in vehicles traveling over the magnet installation that indicate the transverse location of the vehicles with respect to the magnet installation.

9. A vehicle guidance track on a roadway comprising a set of magnet installations aligned in spaced relation on a longitudinal axis of the roadway, at least a plurality of the magnet installations individually extending in a direction transverse to the longitudinal axis, comprising at least one elongated polymer-based magnet strip, and having a geometric configuration that changes in a predetermined manner over at least part of their transverse extent such that the parts of said transversely extending magnet installation located at a first distance from said longitudinal axis contribute a first set of vector components of magnetic field as measured at a sensing line that is transverse to the longitudinal axis and parallel to the surface of the roadway, and the parts of said magnet installation located at at least one different distance from said longitudinal axis contribute a second set of vector components of magnetic field at said sensing line, the second set of vector components being different from the first set of vector components, whereby electric signals are generated in flux sensors in vehicles traveling over the track that indicate the transverse location of the vehicles on the track.

10. A track of claim 9 in which the magnet installations are installed in a channel in the roadway.

11. A track of claim 9 which exhibits bi-directional symmetry.

12. A track of claim 9 in which the change in geometric configuration is provided by changing the cross-sectional size of said magnet strip over its transverse extent.

* * * * *