United States Patent

[11] 3,617,890

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[73] Assignee Sumitomo Electric Industries, Ltd.
Osaka, Japan
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[33] Japan
[31] 42/2324;
Feb. 16, 1967, Japan, No. 42/9981; Mar. 20, 1967, Japan, No. 42/17274; Mar. 20, 1967, Japan, No. 42/17276; Mar. 20, 1967, Japan, No. 42/17277; Mar. 20, 1967, Japan, No. 42/17278; June 18, 1967, Japan, No. 42/38985

[54] INDUCTION RADIO SYSTEM FOR VEHICLES
9 Claims, 54 Drawing Figs.

[52] U.S. Cl. **325/51,** 179/82, 325/56, 325/305, 340/32, 340/47, 340/258, 343/895
[51] Int. Cl. **H04b 7/10,** H01q 1/36
[50] Field of Search .... 179/82; 191/10; 246/8, 29, 30, 63, 194; 324/70 B; 325/51, 305, 369, 52, 56; 332/45; 340/22, 31, 32, 38, 47, 258; 343/711, 713, 717, 895

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Primary Examiner—Benedict V. Safourek
Attorney—Carothers and Carothers

ABSTRACT: An induction-radio system with a low induced noise level and unwanted radiation level for transmission of communication and control signals between a vehicle following a track and wayside station. The transmission line is positioned in parallel along the track and consists of two conductors helically wound with an equal and constant pitch and the antenna is mounted on the vehicle adjacent the transmission line for continuous coupling therewith. The antenna consists of at least one pair of adjacent elements positioned to receive the carrier current in the transmission line with a phase shift difference of an odd multiple of 90° and a phase combining means connected to the elements additively phase combines the received outputs of the elements.

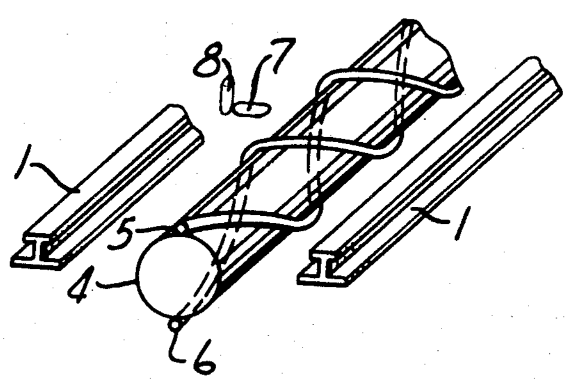

Fig. 1A
PRIOR ART

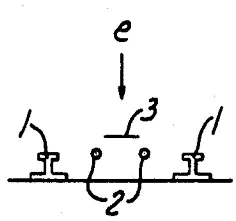

Fig. 1B
PRIOR ART

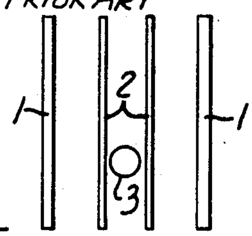

Fig. 2A
PRIOR ART

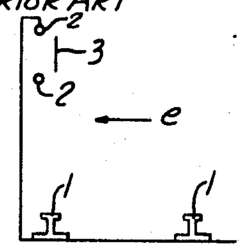

Fig. 2B
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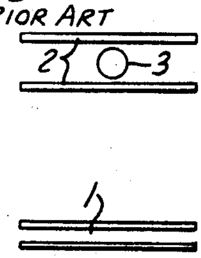

Fig. 3A
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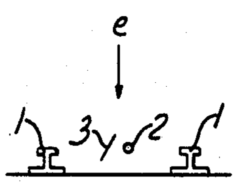

Fig. 3B
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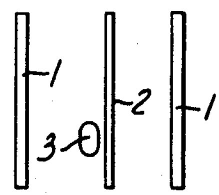

Fig. 4A
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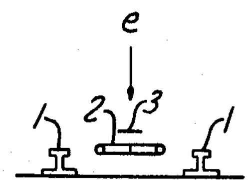


Fig. 4B
PRIOR ART

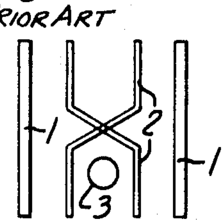
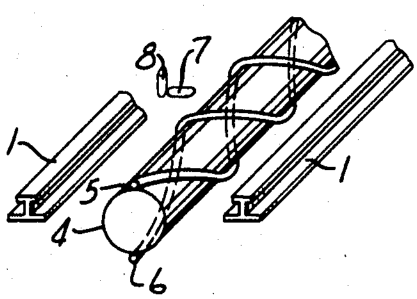


Fig. 5



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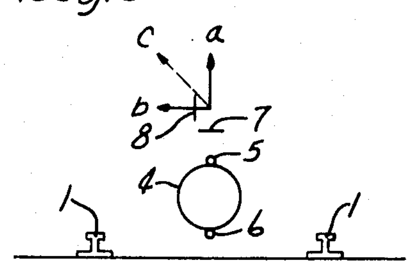

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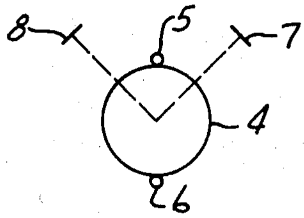

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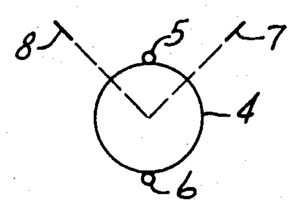

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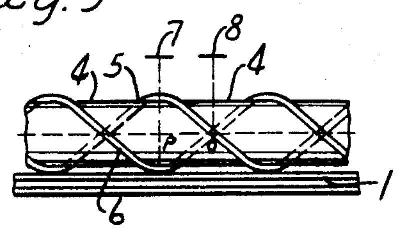
Fig. 9



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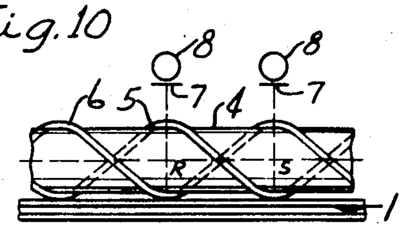

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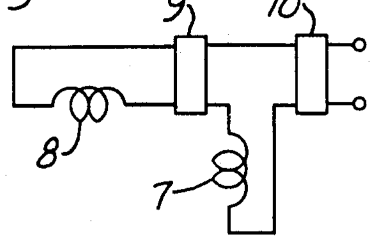

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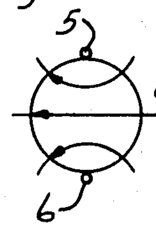

Fig. 12B

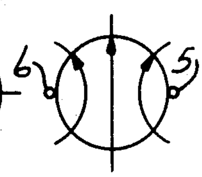

Fig. 12C

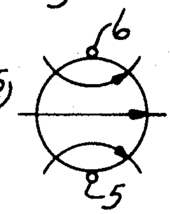

Fig. 13A

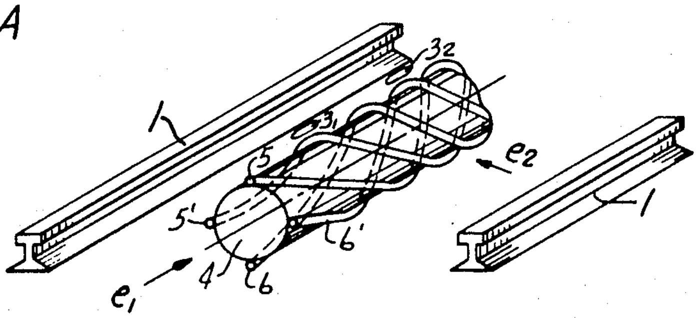

Fig. 13B

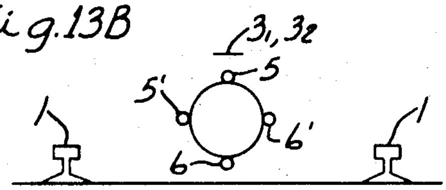

Fig. 13C

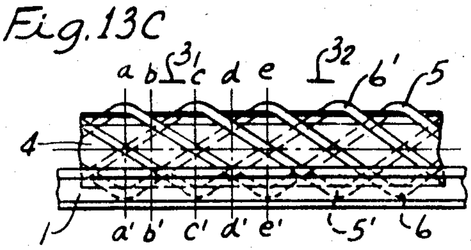

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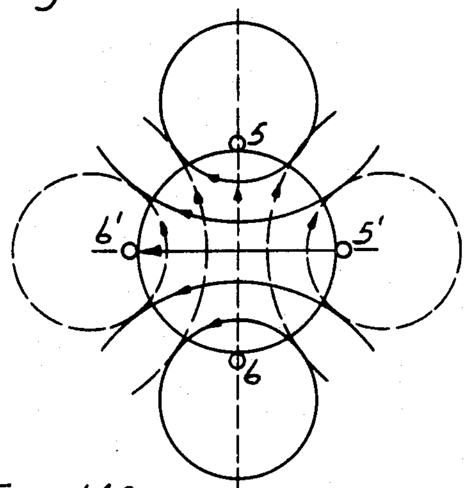
Fig. 14A



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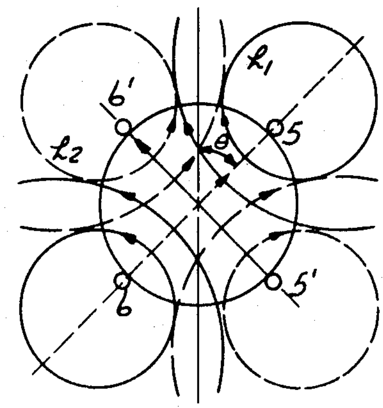


Fig. 14C

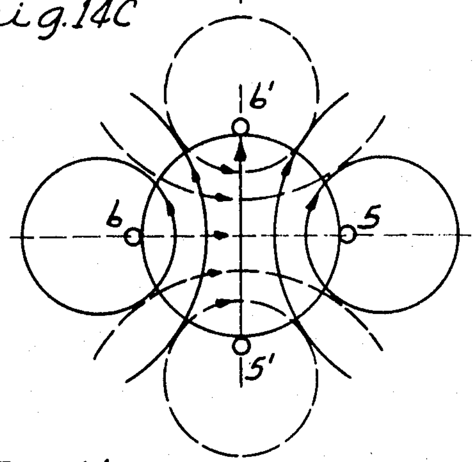


Fig. 14D

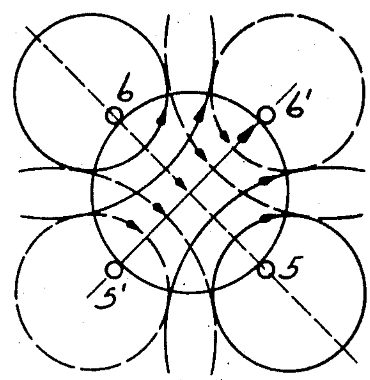
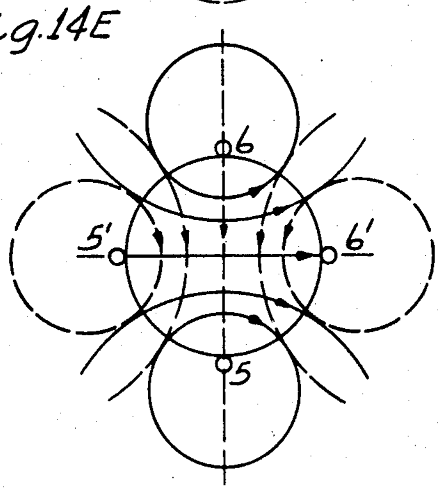


Fig. 14E



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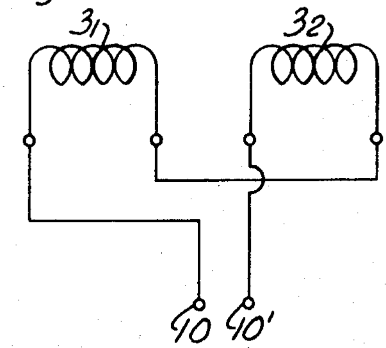

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Fig. 16

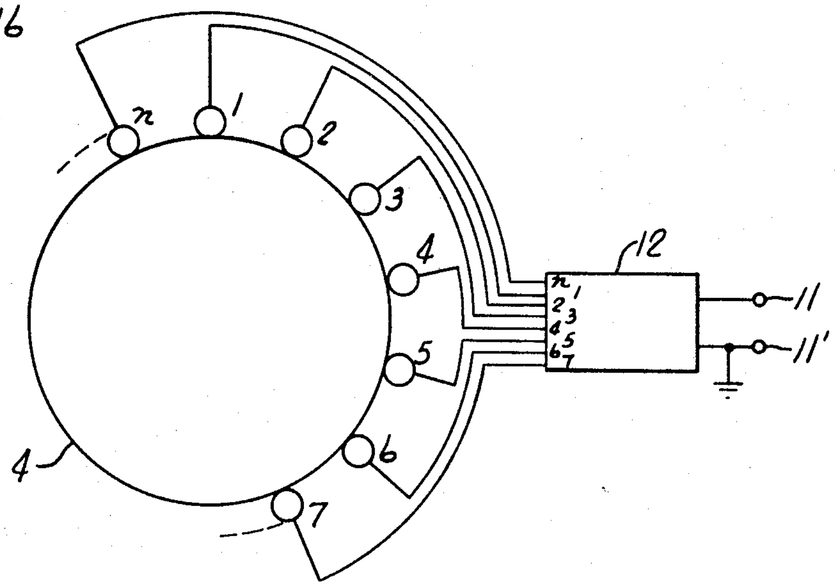


Fig. 17A

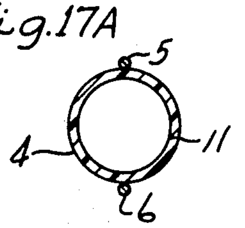
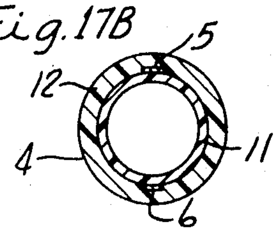


Fig. 17B



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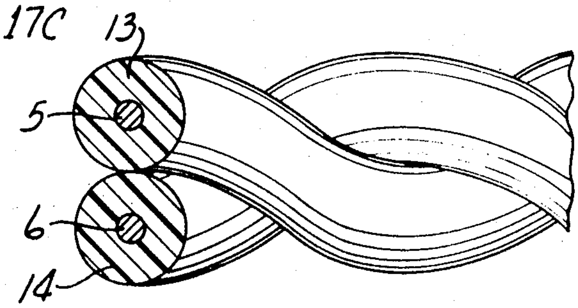

Fig. 17D

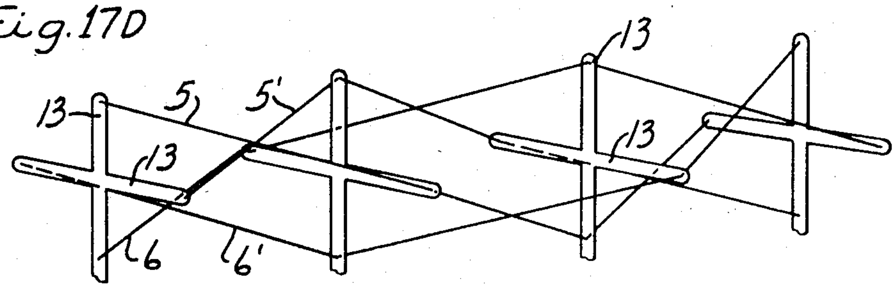

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Fig. 17F

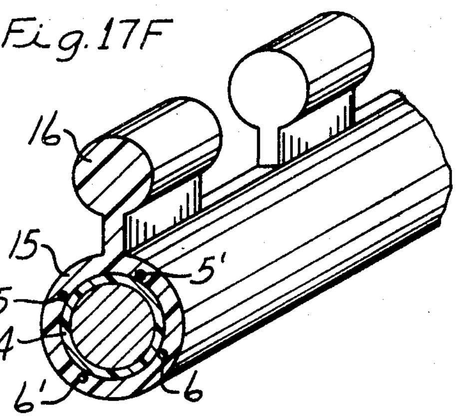


Fig. 17G

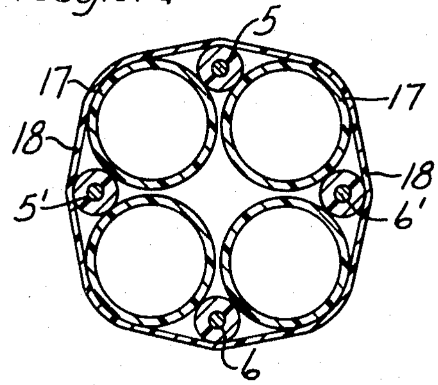


Fig. 17H

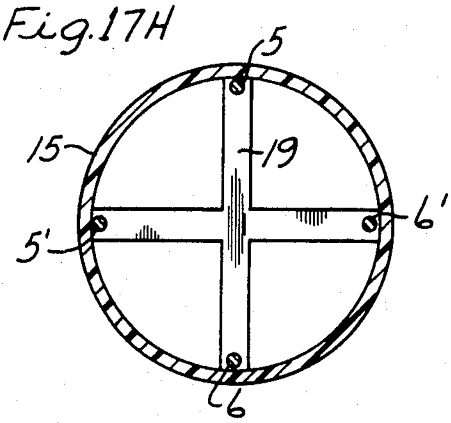
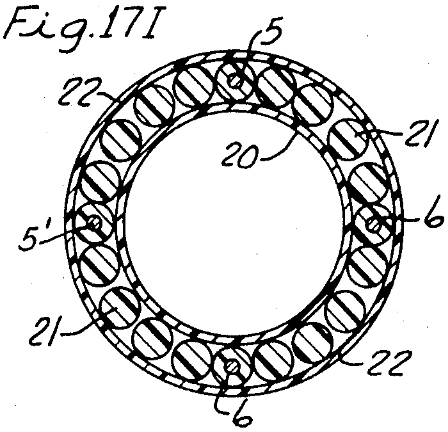


Fig. 17I



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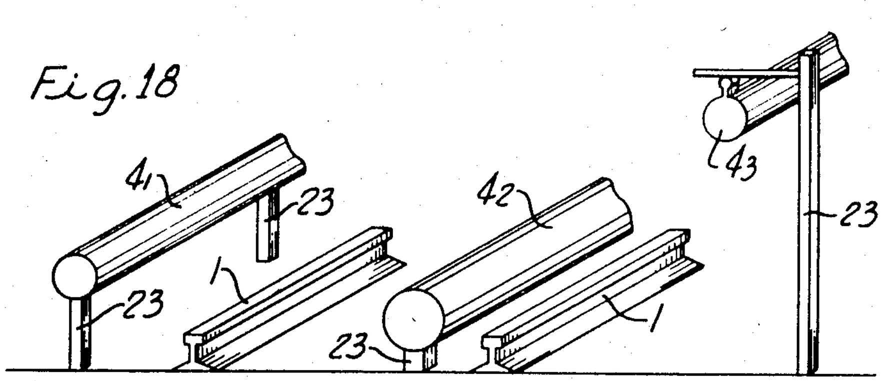
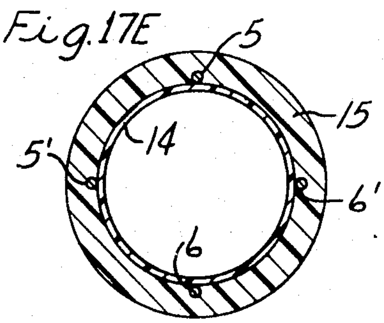


Fig. 17E



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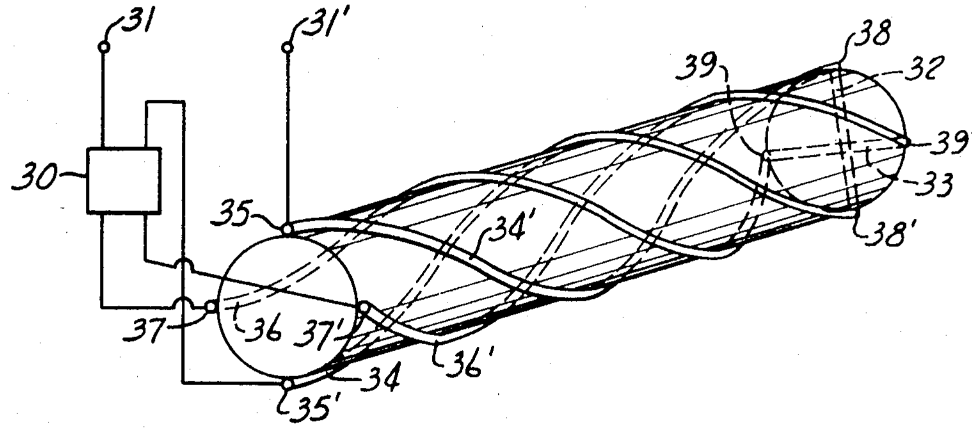

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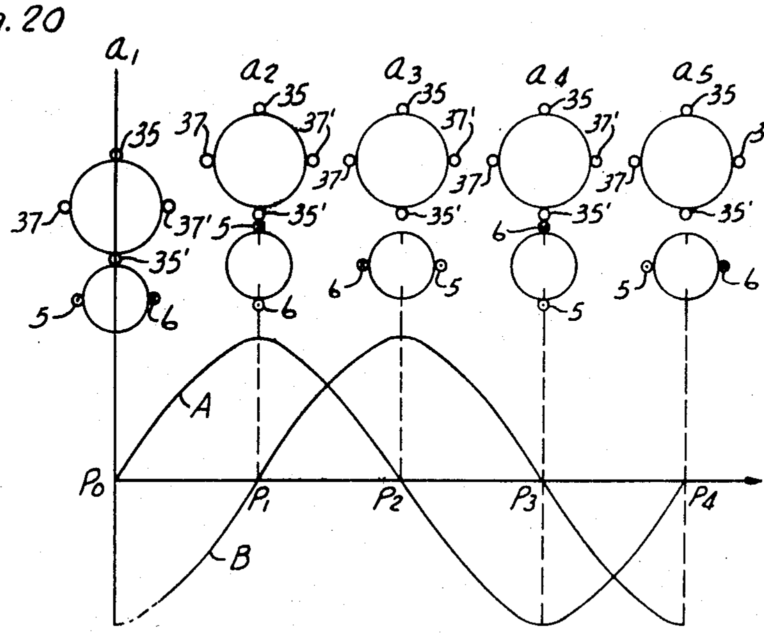

Fig.20

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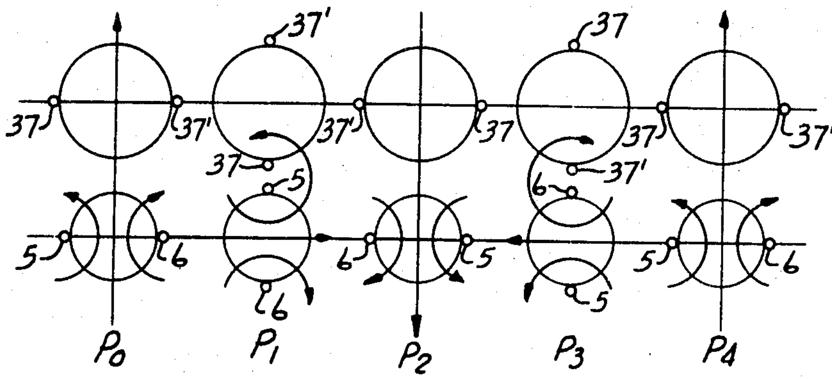
Fig. 21



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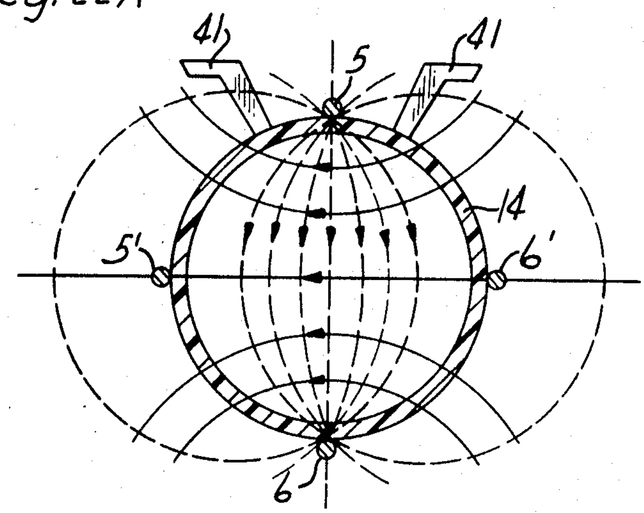

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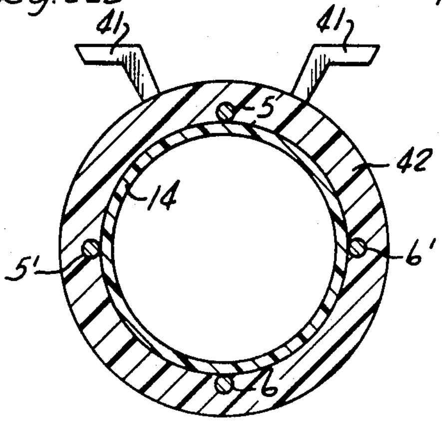
Fig. 22B



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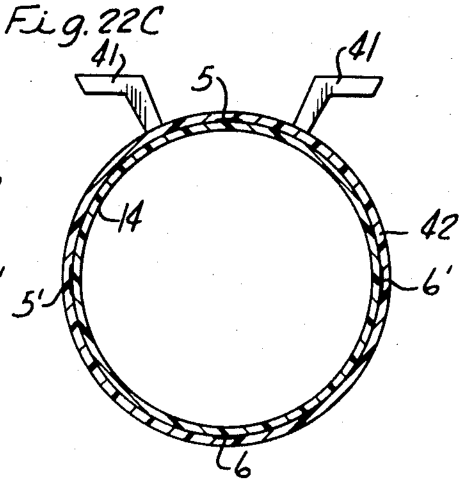

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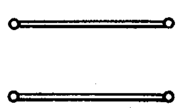


Fig. 23B

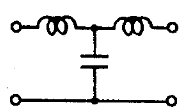
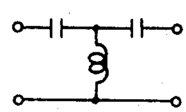


Fig. 23C



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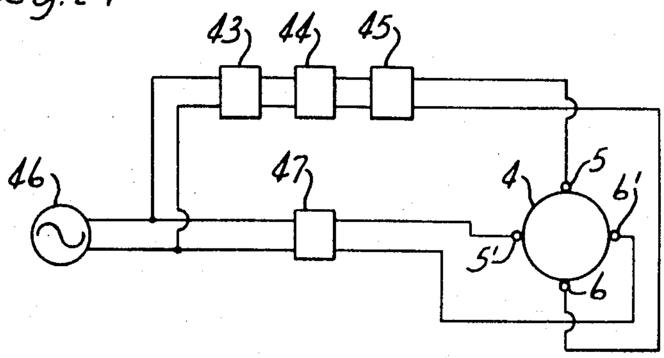

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Fig. 25

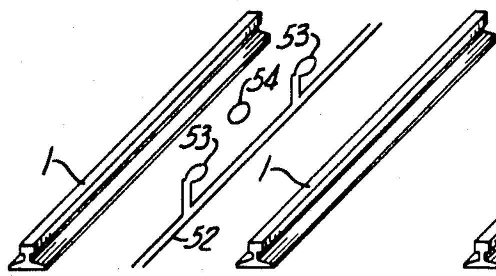


Fig. 26

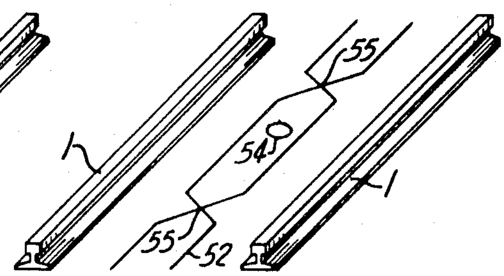


Fig. 27

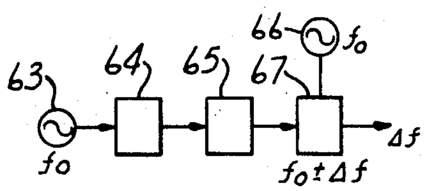


Fig. 28

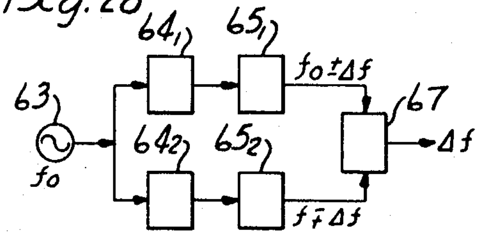


Fig. 29

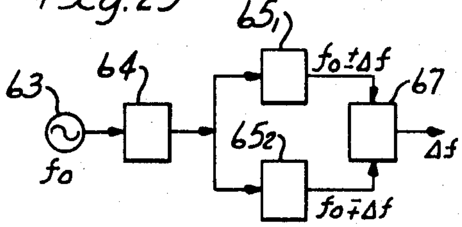
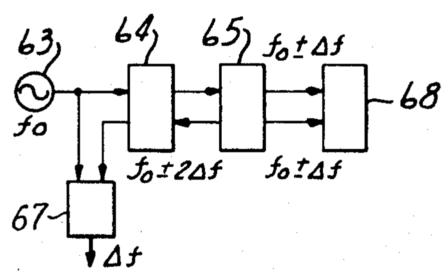


Fig. 30



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INDUCTION RADIO SYSTEM FOR VEHICLES

BACKGROUND OF THIS INVENTION

1. Field of the Invention

This invention relates to an induction radio system for vehicles or trains using an improved transmission line and an antenna aboard the vehicle.

2. Description of the Prior Art

The conventional induction radio transmission systems have been constructed as shown in FIG. 1, 2, 3 and 4. These have the shortcomings explained as follows:

Referring to FIG. 1, FIG. 2, Fig. 3 and FIG. 4, it is to be noted that the A figures show the systems as seen in the direction of the track and the B figures show a view of the system as seen in the direction of *e* of the A figures.

First there is a known system, as shown in FIG. 1, wherein two transmission wires **2** are installed in parallel to rails **1** at equal heights from the ground and a loop antenna **3** coupling with the electromagnetic fields created along the transmission wires is provided aboard the train for sending and receiving signals. There is also a known system that as shown in FIG. 2, wherein two transmission wires **2** are installed in a vertical plane which extends parallel with rails **1** and an antenna **3** for the transmission wires **2** is provided on board the train.

FIG. 1 and 2 illustrate systems wherein the transmission line consists of two parallel conducting wires installed along a track and a loop antenna aboard the train couples with the magnetic field of the line. These systems have high induced noise levels and high unwanted radiation levels because of their construction.

The system shown in FIG. 3 is such that one transmission wire **2** is installed in parallel to the rails **1** and an antenna is coupled with the wire and mounted on board the train. The electromagnetic field created between the one transmission wire **2** and the ground is coupled with the antenna **3** for communication. The system as shown in FIG. 3 has a further fatal shortcoming. That is to say, a part of the transmitted electromagnetic wave energy propagates along the ground, and hence realization of the uniformity in the transmission line is very difficult.

The system shown in FIG. 4 is such that two transmission wires **2** extend parallel to the rails and are crossed in a plane which is substantially parallel to the ground and an antenna for these transmission wires is provided aboard a train.

The system described in FIG. 4 has the periodically arranged cross points of two conducting wires to provide a transmission line which will suppress induced and unwanted noises from outside radiation of other communication systems to a low level. But this system cannot use a high-frequency signal because the transmission frequency characteristic of high-frequency waves is influenced by the capacity existing at the cross points of the two transmission wires, and the cross points of the transmission line cause interruptions of the coupled signal between the transmission line and an antenna aboard the train. This causes noises in the communication signal.

In the case of the systems shown in FIG. 1, FIG. 2, FIG. 3 and FIG. 4, all the transmissions wires are installed in a parallel plane near to the ground, so that foreign bodies find their way into the space where the electromagnetic field is created and degrade the transmission characteristics, while at the same time they create radiation to the outside and interfere with other communication systems. They are also found to be obstacles to the maintenance of the railroad track. Also in the case of the systems shown in FIG. 1, FIG. 2, FIG. 3 and FIG. 4, it is impossible to repress entry of outside noise into the antenna and power radiated outside from the antenna, because the systems use a single antenna.

SUMMARY OF THE INVENTION

The induction-radio system of the present invention is provided for vehicles following a track wherein a transmission line is positioned in parallel along the track and consists of two conductors helically wound with an equal and constant pitch around the axis of the transmission line with the conductors circumferentially separated by one-half of the aforesaid pitch. A transmission source is connected to the line to transmit an intelligence modulated carrier frequency current thereon. An antenna is mounted on the vehicle adjacent the transmission line for continuous coupling with the magnetic flux produced by the flow of set carrier current in the transmission line. A receiver on the vehicle is connected to receive the received output of the antenna which has at least one pair of adjacent antenna elements positioned to receive the carrier current respectively with a phase shift difference of an odd multiple of 90° therebetween, and a phase combining means is connected to the elements to additively phase combine the received outputs thereof to provide a received antenna output for said receiver having a uniform signal receiving level when the vehicle is moving or traveling.

The transmission line of the present invention makes it possible to maintain a uniform space between two wires along the line axis as they are wound on the cylindrical surface. Consequently, the transmission characteristics at high frequencies (50 kHz. to 400 kHz.) do not degrade, so that a broad band transmission is possible.

A further object of the invention is to provide an induction radio system preventing noise from entering both the transmission line and the antenna of the vehicular induction-radio system from outside, eliminating unwanted radiation from both the transmission line and the antenna which interferes with outside communication systems.

A still further object of the invention is to provide an induction radio system which prevents obstacles from entering the space between the conducting wires where most of electromagnetic energy is concentrated.

A still further object is to provide the induction-radio system having an antenna aboard the train, this antenna being constructed by helically winding conducting wires on a cylindrical surface, and thereby eliminating unwanted radiation.

A still further object is to provide the induction radio system having an improved phase combiner with uniform phase-shifting characteristics in a wide frequency band. A still further object is to provide an improved vehicle speed detector by using the induction-radio system of this invention.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawings, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1*a* is a diagrammatic transverse-sectional view in elevation of a two-wire induction radio-transmission system in the prior art for railroad use.

FIG. 1*b* is a diagrammatic plan view of the system illustrated in FIG. 1*a*.

FIG. 2*a* is a diagrammatic transverse-sectional view in elevation of another two-wire induction radio-transmission system in the prior art for railroad use.

FIG. 2*b* is is a diagrammatic view in side elevation of the system illustrated in FIG. 2*a* as viewed in the E direction indicated in FIG. 2*a*.

FIG. 3*a* is a diagrammatic transverse sectional view in elevation of a single-wire induction radio-transmission system for railroad use in the prior art.

FIG. 3*b* is a diagrammatic plan view of the system illustrated in FIG. 3*a*.

FIG. 4*a* is a diagrammatic transverse-sectional view in elevation illustrating a periodically reversed two-wire induction radio-transmission system for railroad use as found in the prior art.

FIG. 4*b* is a diagrammatic plan view of the system illustrated in FIG. 4*a*.

FIG. 5 is a diagrammatic perspective view of one embodiment of the two-wire induction radio-transmission system of the present invention.

FIG. 6 is a transverse diagrammatic sectional view in front elevation of the system shown in FIG. 5.

FIG. 7 is a diagrammatic transverse-sectional view in front elevation showing a variation of the antenna structure arrangement illustrated in FIG. 5.

FIG. 8 is a diagrammatic sectional view in front elevation illustrating another embodiment of the antenna structure incorporated in the system of the present invention.

FIG. 9 is a diagrammatic view in side elevation illustrating a fourth antenna arrangement for the transmission system of the present invention.

FIG. 10 is a diagrammatic view in side elevation illustrating still another embodiment or arrangement of the antenna for the transmission system of the present invention.

FIG. 11 is a schematic drawing illustrating the electrical connections of the antenna elements illustrated in FIGS. 5 through 10.

FIGS. 12*a*, 12*b*, and 12*c* are diagrammatic views illustrating the magnetic fields in a cross section of the transmission line of the present invention as respectively seen at adjacent one-fourth-pitch intervals therealong.

FIG. 13*a* is a diagrammatic perspective view illustrating a different construction of the induction-radio system of the present invention wherein more than two conductors comprise the transmission line.

FIG. 13*b* is a diagrammatic sectional view in front elevation of the system illustrated in FIG. 13*a*.

FIG. 13*c* is a diagrammatic view in side elevation of the system illustrated in FIG. 13*a*.

FIGS. 14*a*, 14*b*, 14*c*, 14*d*, and 14*e* are diagrammatic sketches illustrating the magnetic fields at points (a–a'), (b–b'), (c–c'), (d–d'), and (e–e') as shown in the structure of FIG. 13*c* respectively.

FIG. 15 is a schematic diagram illustrating the connection of the two antenna elements illustrated in FIG. 13*a*.

FIG. 16 is a schematic diagram illustrating the connection of a transmission line of the present invention having *n*-conducting wires and an *n*-phase converter.

FIG. 17*a* is a transverse sectional view illustrating one embodiment of the transmission-line structure of the present invention.

FIG. 17*b* is a transverse sectional view of the transmission line of the present invention illustrating another embodiment of the structure thereof.

FIG. 17*c* is a perspective view of the two-wire-transmission system of the present invention illustrating another embodiment of manufacture of the transmission line of the present invention.

FIG. 17*d* is a perspective view illustrating a further embodiment of the physical structure of the transmission line incorporated in the system of the present invention wherein four conductors are employed.

FIG. 17*f* is a perspective view illustrating another embodiment of the transmission-line structure for a four-line transmission line employed in the system of the present invention as illustrated in FIG. 17*d*.

FIGS. 17*g*, 17*h*, 17*i*, and 17*e* are cross-sectional views of four different four-wire transmission lines of the present invention respectively illustrating different methods of providing the helical transmission-line structure of the present invention.

FIG. 18 is a perspective view of one embodiment of the present invention illustrating the actual installation of the transmission line in relation to the vehicle tracks.

FIG. 19 is a diagrammatic perspective view illustrating another embodiment of the antenna which may be employed in the two-wire transmission-line system of the present invention.

FIG. 20 is a diagrammatic sketch and graph illustrating variations in the axial direction of the total signal-receiving voltage illustrating the function of the antenna as shown in FIG. 19.

FIG. 21 is a diagrammatic graphical sketch illustrating variations in the axial direction of the coupling condition between the two-wire transmission line of the present invention and an antenna therefor.

FIGS. 22*a*, 22*b*, and 22*c* are cross-sectional views illustrating a different embodiments respectively of the antenna structure shown in FIG. 19.

FIGS. 23*a*, 23*b*, and 23*c* are schematic diagrams respectively illustrating three different examples of circuits which may be employed for shifting the phase in the antenna employed in the induction-radio system of the present invention.

FIG. 24 is a schematic diagram illustrating a phase-shifting circuit which may be employed in the system of the present invention.

FIG. 25 is a diagrammatic perspective view illustrating an induction-radio system capable of detecting the vehicular speed.

FIG. 26 is a diagrammatic perspective view illustrating another embodiment of the structure shown in FIG. 25.

FIG. 27, FIG. 28, FIG. 29, and FIG. 30 are respectively schematic block diagrams illustrating embodiments of the speed detection circuits used in conjunction with the vehicular speed detectors shown in FIGS. 25 and 26.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An example of an induction radio system for vehicles or trains embodying the principles of the present invention is explained, with reference to FIG. 5 and FIG. 6.

The transmission line is provided by helically winding at an equal and constant pitch two conducting wires 5 and 6 axially separated by one-half of the winding pitch in the direction of the cylindrical axis on the surface of a cylinder 4 parallel to the rails 1.

The antenna consists of two elements 7 and 8 are provided such that when the detecting amplitude of one of them is the maximum, the detecting amplitude of the other becomes the minimum and are mounted aboard the vehicle moving on the rails 1 and along this transmission line in such a manner that the planes of the antenna elements cross each other at right angles at a point in a plan normal to the transmission axis.

As shown in FIG. 11, the two antennas 7 and 8 are connected to the composite circuit 10 via a circuit 9 which shifts by $\pi/2$ the phase of the current induced in the antenna 8.

A transmission signal is sent to the two conducting wires helically wound around the cylindrical surface 4. Induced voltages appear respectively in the antennas 7 and 8 which couple with the magnetic fields accompanying these conducting wires 5 and 6. The current created by the induced voltage of the antenna element 8 is phase-shifted by $\pi/2$ by the circuit 9 and then combined with the current created by the induced voltage of the antenna element 7 via the circuit 10 to obtain a receiving signal.

The relationship between the conducting wires 5 and 6 and the magnetic fields is as shown in FIG. 12. FIG. 12A shows with arrows the directions of a magnetic field at a point where the conducting wires 5 and 6 are positioned vertically. At a point one-fourth of the winding pitch further from that point, the conducting wires 5 and 6 are positioned horizontally as shown in FIG. 12B and the directions of the magnetic field are as shown by the arrows. At a point one-fourth pitch still further from this point, namely at a point one-half pitch further from the point of FIG. 12A, the conducting wires 5 and 6 are positioned vertically and the directions of the magnetic field are as shown by the arrows.

That is to say, when a transmission signal is sent to two conducting wires helically wound and separated from each other by one-half of the winding pitch, the spatial distribution direction of the magnetic field accompanying the transmission line is reversed at points separated from each other by one-half of the winding pitch in the direction of the transmission line.

As a result, the radiation fields leaking to the outside from the transmission line which consists of two conducting wires 5 and 6 cancel each other at every one-half of the winding pitch and become effectively zero. This results in the prevention of interference with outside communication systems.

Conversely, electromagnetic fields invading from the outside induce electric current of antiphase at every one-half winding pitch in the transmission line and cancel each other, thus becoming effectively zero. This results in the prevention of the invading noise from outside into the transmission line. The two antenna elements 7 and 8 provided aboard the vehicle moving on the rails 1 along the transmission line are so positioned that two planes in which they lie are normal to each other at a point in a third plane normal to the transmission axis, so that the antenna element 7 detects the magnetic field in the direction *a* and the antenna element 8 detects the magnetic field in the direction *b* which is at a right angle to *a* as shown in FIG. 6. Explained in other words, the magnetic field intensity vectors of antennas 7 and 8 are perpendicular to each other and in a common plane normal to the transmission axis.

Thus, the signal receiving voltage V_c combining the detection voltage V_a of the antenna element 7 and the detection voltage V_b of the antenna element 8 is obtained by the circuit shown in FIG. 11. There is the following relationship between them.

$$|V_c|^2=|V_a|^2+|V_b|^2 \qquad (1)$$

In FIG. 6, the conducting wires 5 and 6 are positioned vertically, so that the magnetic field is directed from right to left, the detection amplitude of antenna element 8 being the maximum and that of the antenna element 7 the minimum, or zero.

At a point one-fourth pitch further from the position of the conducting wires 5 and 6 in FIG. 6, the conducting wires 5 and 6 are positioned horizontally as shown in FIG. 12B, so that the direction of the magnetic field is upwards, the detection amplitude of the antenna element 7 becoming the maximum and that of the antenna element 8 zero, or the minimum.

As mentioned already, when two such antenna elements 7 and 8 are positioned such the two planes including them or in which they lie are normal to each other, the amplitude of induced current in one of them is maximum while the amplitude of the other becomes minimum when they are installed aboard the vehicle moving along the transmission line and the signal-receiving voltage is obtained by the phase-combining circuit as shown in FIG. 11 from the voltages detected by these two antenna elements 7 and 8 respectively. In consequence, a signal-receiving voltage which is uniform at all times is obtained irrespective of the position of the vehicle and its moving speed.

FIG. 7 and FIG. 8 show a system in which two antenna elements 7 and 8 of the antenna are positioned in planes normal to each other which meet at a point in a plane normal to the transmission axis or in other words which meet on a common line of intersection which is parallel with the transmission line. In the case of FIG. 7, the respective planes which include the antenna elements 7 and 8 are made normal to the radical direction with respect to the center of the transmission axis.

FIG. 9 shows a system in which two antenna elements 7 and 8 are installed aboard the vehicle moving along the transmission line as explained in FIG. 5 at two points P and Q which are one-fourth winding pitch apart from each other on the transmission axis so that when the detection amplitude of one of them is maximum, the detection amplitude of the other becomes minimum.

The planes which include the antenna elements 7 and 8 are parallel to each other, and they are provided on a straight line parallel to the transmission axis.

In this case, the antenna elements 7 and 8 are distant from each other by one-fourth of the winding pitch on the transmission axis, so that the directions of magnetic fields at the two points P and Q have a difference of 90°. In consequence, when the detection amplitude of the antenna element 7 is maximum, the detection amplitude of the other antenna element 8 becomes minimum.

If the voltages detected by these two antenna elements 7 and 8 respectively are phase-combined using a circuit as shown in FIG. 11, a composite receiving signal voltage is obtained just as in the case of FIG. 5 and FIG. 6.

FIG. 10 shows a system in which the transmission line is assembled by helically winding two conducting wires 5 and 6 axially separated from each other by one-half the winding pitch in the direction of the cylindrical axis around the cylindrical surface 4 and two sets of antenna elements 7 and 8 are provided at points R and S which are spaced apart by one-half of the winding pitch on the transmission axis such that when the detection amplitude of one of them is maximum, the detection amplitude of the other is minimum are provided aboard the vehicle moving along this transmission line.

The antenna elements 7 and 7 and the antennas 8 and 8 provided at two points along the transmission axis respectively are of mutually parallel directions.

If the voltages detected by the two antenna elements 7 and 8 provided at point R respectively are phase-combined, a composite receiving signal voltage is obtained as in the case of FIG. 5. If the voltages detected by the two antenna elements 7 and 8 provided at point S are phase-combined, a composite receiving signal voltage is likewise obtained. Since point R and point S are distant from each other by one-half of the winding pitch, the directions of the magnetic fields at the two points R and S are in the opposite direction to each other. If the receiving signal voltages combined at point R and point S are added together in reverse direction i.e., the polarity of one is reversed, therefore, it is possible to obtain a double receiving signal voltage and also to suppress the outside noise coupled with the antennas and the interference with other communication systems by radiation from the antennas.

Since two such antenna elements 7 and 8 are provided such that when the detection amplitude of one of them is maximum, the detection amplitude of the other is minimum are provided aboard the vehicle moving along the transmission line, and the receiving signal voltage is obtained, by phase-combining the voltages detected by these two antenna elements 7 and 8 respectively, a constant receiving signal voltage is obtained irrespective of the position of the vehicle and its moving speed.

The coupling level between the transmission line and the coupler system can be kept uniform along the transmission line. The transmission characteristic is uniform and stabilized because the transmission line has a uniform distance between the two wires which are wound on the cylindrical surface and a broadband transmission can be made. It is also possible to avoid such shortcomings as the instantaneous interruption at the cross point of the wires of the transmission line as shown in FIG. 4 caused by movement of the train and changes in coupling level.

In the case where as shown in FIG. 10, two coupled pairs of antennas having elements 7 and 8 are provided at each of two points R and S separated apart by an odd number multiple of one-half of the winding pitch along the transmission axis, and the voltages detected by the two antenna elements 7 and 8 at each of the two points R and S are phase-combined and added together in reverse directions, outside noises entering the system at the two points R and S are cancelled as a result of the addition in reverse directions, so that the entry of noise from outside is prevented and at the same time radiations from the antennas to the outside are also cancelled and interference with other communication systems are prevented.

Other embodiments of the present invention will be explained in detail, referring to the drawings. The embodiments which are explained by FIG. 5–FIG. 10 have a transmission line which is made of a pair of conducting wires opposed or equally spaced apart and wound helically at a constant pitch on a cylindrical surface and two antennas above on a train and the output signals of which are phase-combined to get a uniform receiving signal.

The embodiments which will be explained now, however, have a transmission line which is made of a plurality of conducting wires (n wires, $n\geq 2$) equally spaced apart and wound helically at a constant pitch on a cylindrical surface, n wires being fed in such a manner that the phase difference between a current in a wire and that in its adjacent wire is $2\pi/n$ radians, and a single antenna, as a rule, provided aboard a train.

FIG. 13A is a perspective view showing the construction of an embodiment of this invention. FIG. 13B is a view from e_1 of FIG. A. FIG. 13C is a view from e_2 of FIG. A. In FIG. 13, 1 denotes the rails, 4 the transmission line, 3_1 and 3_2 the receiving antennas.

The transmission line according to this invention is characterized in that four wires (generally, three or more wires) are cubically twisted together. This condition is shown at 5, 6 and 5', 6' in FIG. 13A, B and C. As a result of this arrangement, outside broadcasting electric waves from all directions and outside noises such as those generated by the commutator of the motor of the train, trolley wires, switches, etc. cannot induce current in the transmission line for the reason hereinafter mentioned, while at the same time the power radiated to the outside from the transmission line is cancelled and becomes zero, thus eliminating interference with other communication systems.

FIG. 14A, B, C, D, and E show by a group of curves, including arrows the distribution of magnetic field at a certain instant in the sections (*a–a'*), (*b–b'*), (*c–c'*), (*d–d'*), (*e–e'*) of FIG. 13C respectively. The group of solid lines indicate the magnetic field accompanied by electric current of a transmitted signal flowing in 5, and 6, and the group of dotted lines indicate the magnetic field accompanied by electric current flowing in 5' and 6'. In FIG. 13, the distance between the section (*a–a'*) and section (*e–e'*) corresponds just to one-half of the pitch, and, as is clear from FIG. 14A and E, the directions of spatial distribution of the magnetic fields are opposite to each other. In consequence, radiation fields of the transmitted signal leaking from the line cancel each other ever one-half of the pitch and become effectively zero. Conversely, electromagnetic fields from outside induce current of the inverse phase every one-half of the pitch and also become effectively zero.

In order to satisfy the requirement for uniformity of coupling between the aforementioned transmission line and the antenna aboard the train, it is necessary to carry out the phase shifting of signals at the signal sending end or the signal receiving end. This will be explained below.

The above-mentioned purpose can be attained by feeding two pairs of conducting wires 5 and 6, 5' and 6' (Generally, three or more conducting wires) constituting the transmission line with one and the same signals, each of which has a phase difference of $\pi/2$ (generally, the quotient of 2π divided by the number of conducting wires). This is tantamount to applying 4-phase alternating current to the four conducting wires one by one. Referring to FIG. 14, if the magnetic fields for the pairs are h_1, h_2 respectively, the voltage V induced in the antenna 3 is obtained by the formula given below.

$$V=K(H_1\cos\theta\pm Jh_2\sin\theta) \quad (2)$$

The angle θ in the formula (2) is shown in FIG. 14 and is the displacement angle of the magnetic field to the antenna direction caused by the twist of the conducting wire. K is a constant which is determined by the frequency of the signal current and the area of the antenna. Since $h_1=h_2$ in the formula (—2), it follows that

$$|V|=Kh_1=Kh_2 \quad (3)$$

The formula (3) means a single antenna coupled with said transmission line can effect the same uniform coupling as the uniform coupling in the direction of the line effected by an antenna coupled with the conventional two parallel wire transmission line. Generally speaking, the same result as that shown by the formula (3), namely the result that the signal receiving level $|V|$=constant, can be obtained if the signals with the same amplitude having a phase difference of $2\pi/n$ between adjacent two wires are applied to input terminals through a single-phase *n*-phase converting circuit 12 as shown in FIG. 16, namely, if *n*-phase alternating current is applied to the input terminals.

3_1 and 3_2 in FIG. 13A, B, and C denote antennas aboard the train installed at a distance of one-half pitch from each other. As mentioned in the foregoing description of the transmission line, the directions of spatial distribution of magnetic fields along the transmission line are reversed just at one-half of the pitch, so that the two antennas 3_1 and 3_2 are connected to combine the induced voltages of two antennas as shown in FIG. 15. As a result of such a connection, the signal-receiving power becomes double that of a single antenna. Moreover, outside electric waves and noise directly entering the antennas do not appear at all between output terminals 10 and 10' because the magnitude and phase of the outside electric waves and noise are both equal if the pitch is sufficiently small with respect to the wave length.

It is also possible through the use of the apparatus of this invention to prevent outside broadcasting electric waves from all directions and outside noise caused by the commutator of the motor of the train, pantagraphs, etc. from inducing current in the transmission line and entering it. The transmission line is provided by helically winding conducting wires on a cylindrical surface at a constant pitch, so that the portion of the electromagnetic field propagated along the transmission line which has the greatest electromagnetic magnitude, namely the part where the concentration of the transmission electromagnetic field is greatest is in the space between the conducting wires. This precludes the entry of any obstacles, and makes it possible to prevent the disturbance of the transmission characteristics.

Since the transmission line is constructed by helically winding conducting wires on a cylindrical surface, it is possible to make the transmission line small and compact and mechanically strong. It has a stabilized transmission characteristic and does not interfere with the maintenance work for the railway tracks.

FIG. 17 shows embodiments of the transmission-line structure used in the train induction-radio system. Fig. 18 shows embodiments of the installation of the lines as shown in FIG. 17.

FIG. 17A shows an example of the transmission line. It is made by helically winding two conducting wires (generally, *n* conducting wires *nl*, 2, 3 ...) separated apart one-half of the pitch (generally $1/n$ of the pitch) along the axis on a hollow circular cylinder 11 made of an electric-insulating plastic which may be a hollow elliptic cylinder.

Since a hollow cylinder 11 is provided in the transmission line 4 where electromagnetic field concentrates, this transmission line has a stabilized characteristic. No obstacles enter there to degrade the transmission characteristic and no rain or moisture can enter there to increase transmission loss. Furthermore, as the spacing between the two conducting wires 5 and 6 can be maintained at a uniform value, the transmission characteristics at high frequency are not degraded.

FIG. 17B shows a transmission line made by helically winding two tape-form conducting wires 5 and 6 generally *n* tape-form conducting wires *n:* 2, 3, ...) separated from each other one-half (generally $1/n$) of the pitch along the axis of a hollow cylinder 11 made of electric-insulating plastic and providing over them an electric-insulating covering layer 12 of polyvinyl chloride, polyethylene, etc.

The provision of a covering layer 12 protects the conducting wires 5 and 6 and at the same time helps the conducting wires 5 and 6 stick to the hollow cylinder 11, thereby preventing disorder in the pitch and displacement of the conducting wires 5 and 6.

FIG. 17C shows another example of the transmission line. It consists of conducting wires 5 and 6 (generally *n* wires) each covered with an electric insulating sheath which are stranded together.

FIG. 17D shows the simplest construction. It is constructed by supporting four (generally three or more) conducting wires 5, 6, 5' and 6' by means of supporters 13, such as porcelain insulators, in such a manner that their spacing conforms to the design value. In this case, the conducting wires will have the form of a zigzag lines instead of continuous curves.

FIG. 17E shows a construction in which conductors 5, 6 and 5', 6' are provided with a covering 15 of polyvinyl chloride or the like in order to protect the conducting wires and also to help the conducting wires stick to the plastic cylinder **14**, making it possible to preclude disorder in the pitch and displacement of the conducting wires. FIG. 17F shows hanger parts **16** made as an extension of the covering **15** in the construction of these transmission lines, except those of C and D aforementioned, when used as an aerial line.

FIG. 17G shows a construction obtained by arranging four pipes (generally, n pipes: $n \geqq 3$) as shown in the drawing, further placing four (generally $n, n \geqq 3$) conducting wires **5, 6** and **5', 6'** as shown in the drawing, twisting them together and wrapping them together with polyethylene tape **18** or the like to keep them in place.

FIG. 17H shows a construction in which conducting wires **5, 6, 5'**, and **6'** are buried in the four ends of the cross-shaped plastic or supports **1a** (generally, a shape having n radial arms) and a covering **15** is provided.

FIG. 17I shows a construction in which four (generally, n: n 3) conducting wires **5, 6** and **5', 6'** are placed equidistantly on a plastic cylinder **20**, filling the gaps with cords **21** of plastic or the like, and providing them with a covering **22**.

In the foregoing figures showing embodiments of the present invention, the cylinder on which conducting wires are wound is shown as having a circular cross section. However, the section of a cylinder need not necessary be a circle but may be elliptical or otherwise.

FIG. 18 shows an example of the transmission line installed. **1** denotes the rail, 4_1, 4_2, and 4_3 the transmission lines, and **23** the supports supporting these lines. The transmission line 4_1 is supported on high supports beside a rail track, 4_2 is supported on low supports between the rails, and 4_3 is suspended from a support besides a rail.

The ordinary loop antennas, loop antennas having ferrite core in them, etc. are used as signal sending and receiving antennas coupling with the magnetic field of the transmission lines as explained.

The antenna element used in the induction-radio system of the present invention are loop antennas, loop antennas having ferrite cores in them, etc. as already mentioned. However, the antenna embodiment described below is that of a type unique to the induction-radio system of the present invention.

As shown in FIG. 19, the antennas for the train induction radio of this invention have a construction in which two pairs of twisted wires having the same pitch as the transmission line are assembled and separated axially from each other by one-fourth pitch and their terminals are short-circuited by short-circuit wires **32** and **33**. The opposed shunted pairs thus provide two separate antenna elements. It is suitable that the length of the antenna, i.e. P_0 to P_4 in FIG. 20, is equal to the pitch multiplied by an integer. As the length increases, the amount coupled is also increased. The signal-receiving system using the antennas of this invention is one in which the receiving signal voltages of the pairs constituting the antenna are phase-combined by means of the phase-combining circuit **30**. **31** and **31'** are terminals. These will be explained in detail below.

Referring to FIG. 19, the receiving signal voltages of the antenna pair or element **34, 34'** vary sinusoidally as indicated by the curve A in FIG. 24 depending on the position of the terminals **35, 35'** of the pair or element **34, 34'**. On the other hand, the receiving signal voltages of the pair or antenna element **36, 36'** vary sinusoidally as indicated by the curve B having a spatial phase difference of $\pi/2$ from the curve A in FIG 20, depending on the position of the terminals **37, 37'** of the pair element **36, 36'**. The receiving signal voltage becomes maximum at the points where the positional relationship between the conducting wires **34** and **34'** or **36** and **36'** constituting the antenna, and the conducting wires **5, 6** constituting the transmission line become as shown by the sections $a_2\,a_4$ or a_1, a_3, and a_5, while the receiving signal voltage becomes zero in the section a_1, a_3, and a_5 or a_2 and a_4 and respectively. If such two receiving signal voltages having a phase difference of $\pi/2$ are compounded by giving them temporal or an additional phase difference of $\pi/2$, it is made possible to realize a uniform receiving signal level independent of the position of the antenna. The reason for this is as follows: If the receiving signal voltage of the pairs **34, 34'** is $V_A = A\sin(2\pi/P)Z$, and the receiving signal voltage of the pair **36, 36'** is $V_b = A\cos(2\pi/p)Z$, then, by giving temporal phase difference of $\pi/2$, the compound voltage V_r is reduced to the following equation:

$$V_r = V_a + jV_B$$
$$= A\sin(2\pi/P)Z \pm JA\cos(2\pi/P)Z$$

Hence,

$$|V_r|^2 = |V_A|^2 + |V_B|^2 = A\sin^2(2\pi/P)Z + A^2\cos^2(2\pi/P)Z = A^2$$

Thus receiving signal voltage level can never be zero.

It is preferable that the direction of twist of the conducting wires of the antenna is opposite to the direction of twist of the wires of the transmission line. This will be explained below.

FIG. 21 shows the positional relationship along the transmission axis between antenna element **36–36'** and conductors **5–6** when the rear end of element **37** and **37'** of the antenna is in the position of a_1 in FIG. 20 with respect to the transmission line, and the penetration of the magnetic field is generated by conductors **5–6** through element **36–36'**. From the Figure it can be seen that voltages induced in antenna element **36–36'** are added together at each point. That is to say, the polarity of the induced voltage is of the same phase along the antenna element. This will not be the case if the direction of twist of the antenna is the same as that of the transmission line.

The receiving signal voltage level increases as the length of the antenna increases. However, the length must be an integral multiple of the pitch. If the length is an integral multiple of the pitch, electromagnetic fields of reverse spatial directions are created every one-half pitch when it is used as a signal sending antenna, the reason being the same as that already mentioned in connection with the transmission line. Thus the radiation power to outside becomes zero. However, signals are effectively excited on the line because of its twist structure with the same pitch as that of the antenna and in the opposite-twisting direction to the antenna.

FIGS. 22 show examples of the antenna of this invention.

FIG. 22A shows an antenna made of a plastic pipe on which four conducting wires **5, 6, 5'** and **6'** are helically wound in the same direction and at the same pitch. In this Figure, the group of broken lines having arrows show the spatial distribution of the electric field, and the group of solid lines having arrows shows the spatial distribution of the magnetic field. From this Figure, it should be noted that the electromagnetic field concentrates in the cylinder **14**, so that the characteristics of the antenna become stable, there being no degradation of properties due to entry of obstacles and no degradation of properties due to rain or moisture, **41** denotes an example of installation fittings.

FIG. 22B shows an construction in which the conducting wires **5, 6, 5'** and **6'** of A are provided with a covering **42** made of polyvinyl chloride or the like in order to protect the conducting wires and aid in securing the conducting wires to the plastic cylinder **14**, which makes it possible to prevent disorder of the pitch and displacement of the conducting wires.

FIG. 22C shows a construction in which the conducting wires **5, 6, 5'** and **6'** of B are replaced with foil tapes so as to make the covering **42** thinner.

FIGS. 23 show examples of circuits for phase shifting.

FIG. 23A shows an example where a delay line is used; the change of phase generally is proportionate to the length of the line. FIG. 23B and C show the circuits which utilize inductance and capacity.

FIG. 24 shows another embodiment of a phase-shifting device. If this device is used, it becomes possible to obtain a uniform characteristic over a broad band.

This phase-shifting device is characterized in that a signal having a constant phase shift is obtained by demodulating the signal which is phase-shifted by a constant amount for a single side band component which is produced by modulation at a very high frequency compared with the frequency of the signal to be transmitted in the line. In the induction-radio system, receiving electrical signals by phase-compounding electrical signals, makes the phase characteristic uniform over a broad frequency band and improves the system characteristics.

In this case, as shown in FIG. **24**, the electrical signal from the power source **46** is subjected to single sideband modulation at high frequency by a single-sideband modulation circuit **43** and then its phase is shifted by a constant amount by a phase-shifting circuit **44**, then detected by a demodulation circuit **45** to be sent to the conducting wires **5** and **6** of the transmission line, and at the same time the electrical signal from the power source **46** is sent to the conducting wires **5'** and **6'** of the transmission line via the circuit **47** for making its amplitude equal to that of said phase-shifted signal. The two electrical signals fed to wires **5** and **6** and wires **5'** and **6'** of the transmission line which have phases different by $\pi/2$ are uniformly received by a single antenna.

When the electrical signal from the power source **46** is subjected to single-sidebond modulation by the single-sideband modulation circuit **43**, the modulated signal will be as shown by the formula below, if the signal of one frequency component in the signal band is represented by $se^{j\omega t}$ and the carrier wave by $ce^{j\omega_0 \theta t}$:

$$ce^{j\omega_0 \phi t} + mse^{j(\omega_0 \phi \pm \omega)t} \quad (4)$$

where c and s are constants and m the degree of modulation.

If the modulated signal represented by the formula (4) is given a phase difference of θ by shifting the phase at a high frequency in the phase-shift circuit **44**, it becomes as shown below.

$$ce^{j\omega_0 \phi t + j\theta} + mse^{j(\omega_0 \phi + \omega)t + j\theta} \quad (5)$$

If this is detected by the demodulation circuit **45** to take out the signal component, then it becomes $m\mu se^{\pm j\omega t + j\theta}$ This means that a signal having a phase difference of θ from the output signal of the source **46** is produced. Here μ is the ratio of change in the amplitude of signal which takes place at the circuit of the demodulation.

If $\omega/\omega_0\theta \ll 1$ in the formula (5), the frequency bandwidth used in the phase-shift circuit **44** to give the phase difference of θ is sufficiently small as compared with the carrier frequency ω_o, so that the phase characteristic in the signal band becomes uniform. According to the present invention, detection is made after shifting the phase of a single-sideband-modulated signal, so that at a high frequency a detected signal having a phase difference of θ from the power source **46** is obtained.

The foregoing refers to a system wherein electrical signals are transmitted to the transmission line and received by an antenna provided aboard a train moving along this transmission line. Needless to say, the same process can be applied to a system wherein electrical signals are fed from an antenna provided aboard the train onto the transmission line for reception.

According to this invention, since an electrical signal fed to the transmission line at a low-frequency band is once modulated by a carrier wave of a high frequency and/or phase shifting, the modulated wave is easily and uniformly made at high frequency, it is therefore possible to ensure good system characteristics.

The induction-radio system of this invention may also be applied to the detection of train speed and train location. The principle of this system is hereinafter explained.

If the time oscillation term is added to the formula (2) to make the complete expression, the received signal Sr will reduce to the following equation:

$$S_r = Soe^{j\omega t} \pm \frac{2\pi^t}{P} \quad (6)$$

where P is the twist pitch in meters If $z=vt$ (v: velocity of the train) is substituted,

$$S_r = Soe^{j\omega t \pm j\frac{2\pi V}{P}t} = Soe^{jt(w \pm \frac{2\pi V}{P})} \quad (7)$$

Hence, the amount of deviation of frequency is:

$$\Delta f = \pm V/P \quad (8)$$

The above formula with respect to the amount of deviation Δf is applicable to both sending and receiving of signals.

This relates to a train speed-detecting system which is characterized in that the speed of a train is obtained by measuring of the frequency deviation Δf of the electrical signal transmitted between the antenna and the transmission line which deviates in proportion to the moving speed of the antenna aboard the train.

The detection of the travelling speed of a train is necessary for the automatic control of a train. For this purpose, the following systems have heretofore been used.

The first of them is a system in which the number of revolutions in a given unit of time or the shaft of wheels of the travelling train is counted to the travelling speed. A second such system is shown in FIG. **25** wherein signal sending elements **53** are periodically provided at fixed intervals on the transmission line **52** installed along the rails **1**. An antenna **54** corresponding to them is provided aboard the train. The number of signals received by the antenna **54** in unit time is counted to find out the speed of the train.

A third such system is as shown in FIG. **26** wherein two conducting wires **52** installed in parallel to the rails **1** are periodically crossed in a plane at fixed intervals. An antenna **54** is provided aboard the train. An electrical signal is transmitted to the conducting wires **52** and the number of interruptions in unit time of the signal received by the antenna **54** at the crosses **55** of the conducting wires **52** is counted to find out the speed of the train.

In case of the first-mentioned system, an error takes place as a result of wear on the wheels, so that it is necessary to make correction for the error. In the case of the second-mentioned system, if the antenna **54** should fail to receive a signal from a signal sending element **53** for some reason or other, the speed detected by the device is lower than the actual speed. This could be a serious safety problem. In addition, this system will be inevitable that it is interfered with by outside noise waves and will interfere with outside communication systems. In the case of the third-mentioned system, the construction is such that an obstacle is likely to find its way into the transmission space between the two conducting wires **52**, causing not only interference with outside communication systems but also a Moreover, transmission loss. Moreover, it obstructs the maintenance work on the railway tracks. Furthermore, the upper limit of the transmission frequencies is restricted under the influence of capacity existing in the neighborhood of the crosses of the two conducting wires, so that the frequency band available for use is narrow. Here also, the number of interruptions in a unit time is counted. As in the case of the second-mentioned system, therefore, the difficulty arises that the detected speed is less than the actual speed if failure to detect interruption should take place for some reason or other.

According to the present invention the above-mentioned shortcomings of the speed detection systems heretofore in use are eliminated. It makes it possible to measure the travelling speed of a train without error. The speed detection system of this invention also possesses many such features such as being free from interference from outside noise waves, avoidance of interference with outside communication systems, effecting a stabilized transmission, and making the construction simple and strong and not obstructing to the maintenance work being done on the railway tracks.

The frequency of the received signal deviates from the frequency of the sending signal by Δf which is proportional to the travelling speed Vm/sec. This deviation amount Δf may be expressed as follows:

$$\Delta f = \pm V/P$$

where p is the twist pitch in meters.

The sign of Δf is determined by the direction of travel of the train, whether the wires are twisted left-hand or right-hand, and the phase-shift direction of the phase-shift circuit as shown in FIG. **11** circuit **9** is for advancing or delaying the phase of the receiving voltage of one antenna with respect to that of the receiving voltage of the other antenna.

Thus it is possible to find out the travelling speed by measuring deviation amount Δf between the frequency of the sending signal sent to the transmission line and the frequency of receiving signal received by the antenna and converting this measured value to the actual speed value.

An embodiment of this invention is shown in FIG. 27. A transmission signal of a frequency fo is sent from the ground station 63 to the transmission line 64. This transmission signal is received by the antenna 65 which couples with magnetic fields accompanied with the transmission line 64 and which is provided on the travelling train.

The frequency of this received signal is $fo\pm\Delta f$, a frequency deviation from the frequency fo of the transmission signal by an amount Δf which is proportional to the speed of the train.

A signal having the same frequency fo as the transmission signal is generated by a local oscillator 66 and given to the mixer 67 together with the received signal and the difference Δf in frequency is measured by the mixer. If this value is calibrated by the pitch of the transmission line 64, the travelling speed v of the train is obtained.

FIG. 28 shows another embodiment. Transmission signal of frequency fo is sent from the ground station 63 to the transmission line 64_1 of right-hand winding and the transmission line 64_2 of left-hand winding. The signal is received by antennas 65_1 65_2 aboard the travelling train which couple with the magnetic fields accompanying the transmission lines 64_1 and 64_2 respectively.

These received signals have deviations of frequency in opposite directions because the directions of winding of the transmission lines are opposite to each other, so that the frequencies of the received signals are $fo\pm\Delta f$ and $fo\mp\Delta f$ respectively.

These receiving signals are put in the mixer 67 and the frequency deviation amount Δf is measured. Then the travelling speed of the train will be determined.

FIG. 29 shows another embodiment. A transmission signal of a frequency fo is sent from the ground station 63 to the transmission line 64; it is received by two antennas 65_1 having the phase shift circuit which advances phase and at the same time by two antennas 65_2 having a phase-shift circuit which delays the phase; the received signals or frequencies $fo\pm\Delta f$ and fo respectively are put in the mixer 67 to measure the deviation amount Δf to determine directly the travelling speed of the train. FIG. 30 shows still another embodiment. A transmission signal of a frequency fo is sent from the ground station 63 to the transmission line 64; the signal is received by the antenna 65 aboard the train; this received signal of a frequency $fo\pm\Delta f$ is amplified by a reflex amplifier 68 and then again sent from the antenna 65 to the transmission line 64 and received by the ground station. The frequency of the signal received by the ground station is $fo\pm2\Delta f$. This is put in a mixer 67 together with the transmission signal of the frequency fo to measure the frequency deviation amount Δf, and then the travelling speed of the train is obtained.

In the case of the speed-detecting systems of this invention, a signal between the transmission line and the antenna is received continuously, so that an interruption in the receiving signal due to some cause or other does not affect the speed detection. This invention makes it possible to prevent outside broadcasting waves, noise generated by the commutator of the motor of the train, pantagraph, etc. from inducing electric current in the transmission line and antennas and thus to eliminate detection errors.

At the same time, electromagnetic fields radiated from the transmission line to the outside cancel each other and become zero every one-half of the pitch of the transmission line, so that it is possible to preclude interference with outside communication systems.

The transmission line is constructed by helically winding two conducting wires separated apart by one-half of the pitch on a cylindrical surface, so that the part of the electromagnetic field propagated along the transmission line which has the greatest electromagnetic intensity, i.e. the part where the concentration of electromagnetic field is great, is the space between the two, helically wound conducting wires. As a result, obstacles will not enter this space, so that the transmission characteristics may be kept stable and the detection error made small. It is possible to keep the coupling of the transmission line and the antenna uniform in the axial direction of the transmission line. Transmission characteristics are stabilized and a broad band transmission is possible because the spacing between conducting wires is kept uniform. Such obstructions to transmission as the instantaneous interruption due to the running of the train and other changes in level can be avoided and the detection error is therefore made small.

As the travelling speed is detected by measuring the deviation amount of the frequency of the transmission signal, it is possible to decrease noise and to make errors small.

If the system of this invention is employed, the travelling speed of the train can be detected by stations both on board the train and on the ground simultaneously.

We claim:

1. An induction-radio system for vehicles following a track comprising a transmission line positioned in parallel with a track and consisting of two conductors helically wound with an equal and constant pitch around a longitudinal axis and axially separated by one-half of said pitch, a transmission signal source connected to said transmission line to transmit an intelligence-modulated carrier-frequency current thereon, antenna means mounted on a vehicle following said track and adjacent said transmission line for continuous coupling with the magnetic flux produced by the flow of said carrier current in said transmission line, a receiver on said vehicle connected to said antenna means, said antenna means having at least one pair of elements positioned relative to each other and said transmission line to receive said carrier current respectively by electromagnetic induction coupling with a spatial phase shift of one-fourth the transmission line winding pitch whereby the receiving level of one of said elements is always maximum when the receiving level of the other element is minimum, and phase-combining means operable to phase shift the received signal of one of said elements by 90° over the signal band of the carrier frequency and to add to it the received output of the other element to obtain an output having a uniform signal-receiving level when said vehicle is moving.

2. The induction-radio system of claim 1 characterized in that said antenna elements in each pair are positioned in respective planes which meet at right angles and are centered in a common plane normal to the axis of said transmission line.

3. The induction-radio system of claim 1 wherein each of said antenna elements is a loop coil.

4. The induction-radio system of claim 1, said antenna means characterized by a plurality of pairs of said antenna elements, each pair of said antenna elements being centrally spaced from each other in the direction of said transmission line by an odd number multiple of one-fourth of the helix pitch of said transmission line, and with each pair positioned substantially the same relative to said transmission line.

5. The induction-radio system of claim 1 characterized in that said antenna means includes two spaced pair of said antenna elements positioned along said transmission line with a center-to-center spacing between pairs of an odd number multiple of one-half of the helix pitch of said transmission line, said phase-combining means operative to reverse the polarity of the output terminals of one of said element pair and interconnecting it to the output terminals of the other.

6. The induction-radio system of claim 1 wherein said antenna means consists of four uniformly spaced conductors helically wound about a longitudinal axis parallel with the axis of said transmission line and with a pitch equal thereto, the opposed pairs of said four antenna conductors being shunted at one end to provide said antenna element pairs and said phase-combining means connected to the terminal ends of the other end of said elements.

7. The induction-radio system of claim 6 characterized in that the winding direction of said helical conductor of said antenna is opposite to that of said transmission line.

8. An induction-radio system for vehicles following a track comprising a transmission line positioned in parallel with a track and consisting of $n\ (n \geqq 3)$ uniformly spaced conductors helically wound with a constant and equal pitch around the axis of said transmission line, signal transmission means connected to said transmission line and operable to transmit an intelligence-modulated carrier-current signal on said transmission line with a phase shift between adjacent conductors of $360/n$ degrees, antenna means mounted on a vehicle following said track and adjacent said transmission line for continuous coupling with the magnetic flux produced by the flow of said carrier current in said transmission line, and a receiver on said vehicle connected to said antenna means.

9. The induction-radio system of claim 8 characterized in that said antenna means is composed of two elements spaced apart in the longitudinal direction of said transmission line by an odd number multiple of one-half of the helical pitch of said transmission line and interconnected to additively combine the received signal outputs thereof.

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