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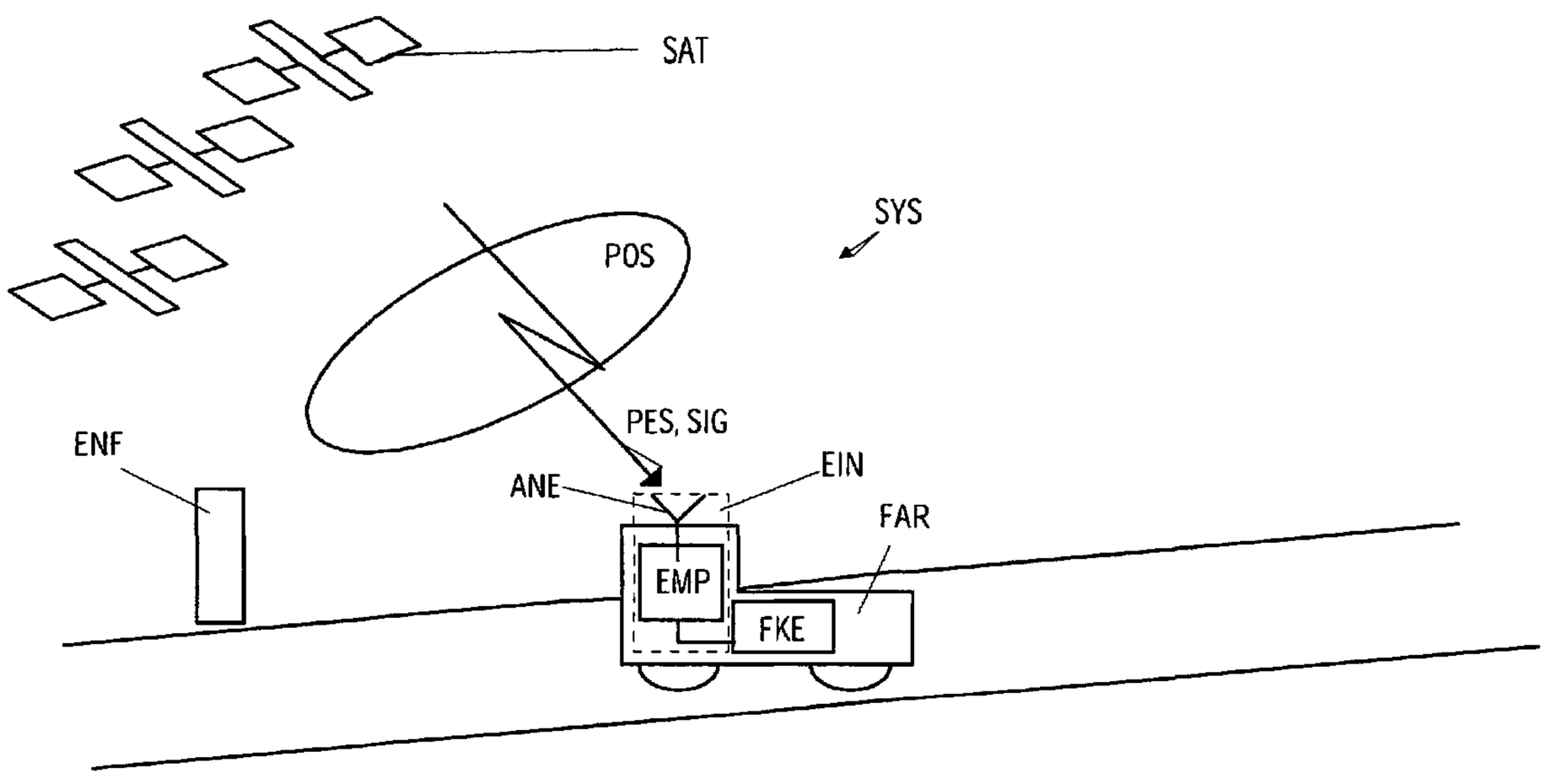
(54) Titre : CONTROLE DE FONCTIONNEMENT AUTOMATIQUE D'UNE UNITE D'ANTENNE D'UNE UNITE DE PEAGE COTE VEHICULE DANS UN SYSTEME DE PEAGE ELECTRONIQUE

(54) Title: AUTOMATIC FUNCTIONAL MONITORING OF AN ANTENNA UNIT FOR A VEHICLE-MOUNTED TOLL-PAYMENT UNIT FOR AN ELECTRONIC TOLL SYSTEM



(57) Abrégé/Abstract:
The invention relates to an automatic function control of an antenna unit (ANE) of a vehicle-mounted toll unit (EIN) of an electronic toll system (SYS) comprising a position detection system (POS). Said toll unit (EIN) comprises a reception unit (EMP) linked with the antenna unit (ANE) and the antenna unit (ANE) is adapted to receive position detection signals (PES). According to the invention, at least one control signal (SIG) that interacts with the antenna unit (ANE) is produced and supplied to the toll unit (EIN), and the function of the antenna unit (ANE) is checked by means of the control signal (SIG).

ABSTRACT

The invention relates to an automatic function control of an antenna unit (ANE) of a vehicle-mounted toll unit (EIN) of an electronic toll system (SYS) comprising a position detection system (POS). Said toll unit (EIN) comprises a reception unit (EMP) linked with the antenna unit (ANE) and the antenna unit (ANE) is adapted to receive position detection signals (PES). According to the invention, at least one control signal (SIG) that interacts with the antenna unit (ANE) is produced and supplied to the toll unit (EIN), and the function of the antenna unit (ANE) is checked by means of the control signal (SIG).

AUTOMATIC FUNCTIONAL MONITORING OF AN ANTENNA UNIT FOR A VEHICLE-MOUNTED TOLL-PAYMENT UNIT FOR AN ELECTRONIC TOLL SYSTEM

The invention relates a method for automatic functional monitoring of an antenna unit for a vehicle-mounted toll-payment unit for an electronic toll system.

The invention furthermore relates to a toll system for electronic toll payment having a position determination system and a vehicle-mounted toll-payment unit, which has an antenna unit and a receiving unit which is connected to the antenna unit, with the antenna unit being designed to receive position determination signals.

A toll system of the type mentioned above has been disclosed in DE 43 44 433 A1. In the known method, current position coordinates are detected by a GPS receiver and are compared with the entry/exit coordinates (which are stored in an electronic label) of a turnpike section and, if the coordinates match, to transmit them by means of the digital mobile network to a payment center which is external to the vehicle, with the distance which has been traveled on the turnpike as well as the turnpike charges associated with this distance being calculated from the transmitted data in the payment center.

WO 95/20801 discloses a toll system for determination of usage charges for roadways and/or traffic areas, in which the position data for the vehicle is detected by means of a position determination system, and is compared with the positions of virtual toll points. In order to calculate the toll charges, the position data can be transmitted to a control center external to the vehicle, in which case the charges may also be

calculated in a toll-payment unit in the vehicle, with the charges determined being transmitted to the control center, where they can then be debited from an account.

WO 99/33027 describes a method for collecting toll charges, in which the current position of the vehicle is compared with the position of the virtual toll point in order to calculate toll charges, with a communication connection being set up between the vehicle and a central toll control point when a vehicle drives through a physical toll station, in order to pay the toll charges incurred. Once a payment transaction has taken place between the toll station and the

vehicle, a communication connection is set up via which verification of correct payment of the toll charge is transmitted.

In electronic toll systems which have a position determination system - for example a satellite-based position determination system such as GPS, in which position data is transmitted via an antenna unit for a vehicle-mounted toll-payment unit to a receiver in the toll-payment unit - the serviceability of the antenna unit is essential in order to make it possible to carry out a correct toll payment. Since the antenna unit is normally arranged on the outside of the vehicle, the antenna unit may become mechanically damaged. If the antenna is covered with aluminum foil, this can also lead to correct toll payment no longer being possible.

One object of the invention is therefore to create a means which allow the serviceability of the antenna unit of a vehicle-mounted toll-payment apparatus to be checked easily and in a cost-effective manner.

This object is achieved by a method for automatic functional monioring of an antenna unit for a vehicle-mounted toll-payment unit for an electronic toll system, having a position determination system, with the toll-payment unit having a receiving unit which is connected to the antenna unit, and the antenna unit being designed to receive position determination signals,

with at least one monitoring signal, which interacts with the antenna unit, being produced, being fed to the toll-payment unit, and the operation of the antenna unit being checked on the basis of the monitoring signal.

For the purposes of this document, the expression signal means both an analog and a digital electrical signal, such as a binary-coded signal or an analog DC/AC voltage, etc. The monitoring signal can on the one hand be used to check whether a signal transmission connection from the antenna unit to the receiver unit is interrupted and, on the other hand, the monitoring signal can also be used to determine electrical characteristics of the signal transmission connection between the antenna unit and the receiver unit. The electrical characteristics of the signal transmission connection of the antenna unit and receiver unit in this case represents a further measure for the serviceability of the antenna unit.

The monitoring signal may be produced as a pilot signal, may be fed to the antenna unit, and the presence of the monitoring signal may be detected at the receiver. In this case,

a pilot signal means a low-power reference signal which is transmitted in addition to the useful signal. By feeding a pilot signal to the antenna unit, it is possible to detect an interruption in the signal transmission connection between the antenna unit and the receiver unit in a simple and cost-effective manner. In one advantageous variant of the invention, the monitoring signal may be transmitted together with the position determination signal.

The monitoring signal is preferably produced at time intervals which can be predetermined.

In one advantageous variant of the invention, the monitoring signal is produced on board the vehicle.

According to the variant of the invention mentioned above, the monitoring signal may be produced by a vehicle-mounted functional monitoring unit which is connected to the toll-payment unit, and may be fed to a signal transmission connection between the antenna unit and the receiving unit, with electrical characteristics and/or reflection characteristics of the signal transmission connection being determined by the functional monitoring unit from a reflected component of the monitoring signal.

The monitoring signal can thus be used to determine values for electrical characteristics and/or reflection characteristics of the signal transmission connection, and to compare these characteristics with nominal values for these characteristics.

Further advantages can be achieved by determining the impedance and/or the operating loss of the signal transmission connection between the antenna unit and the receiving unit.

According to one advantageous embodiment of the invention, the reflection characteristics of the signal transmission connection between the antenna unit and the receiving unit, and/or the electrical characteristics of the signal transmission connection, are determined by means of time domain reflectometry.

If a malfunction of the antenna unit is identified, an appropriate information signal can be produced and can be displayed on the vehicle. This means that it is possible to use the information signal to identify a malfunction of the antenna when passing a monitoring point on the road, and to initiate appropriate measures in order to overcome this defect.

A toll payment system of the type mentioned initially which is particularly suitable for carrying out the method according to the invention is designed to produce at least one monitoring signal, which interacts with the antenna unit, for automatic functional checking of the antenna unit, to feed this to the toll-payment unit, and to check the operation of the antenna unit using the monitoring signal.

In one advantageous embodiment of the invention, the toll system may be designed to produce the monitoring signal as a pilot signal, to feed the monitoring signal to the antenna unit, and to detect the presence of the monitoring signal at the receiver. Furthermore, the toll system can advantageously be designed to transmit the monitoring signal together with the position determination signal.

Furthermore, the toll system may be designed to produce the monitoring signal at time intervals which can be predetermined.

A signal generator for producing the monitoring signal may advantageously be provided on board the vehicle.

Further advantages can be achieved by providing a functional monitoring unit, which is connected to the toll-payment unit, on board the vehicle, and which may be designed to produce the monitoring signal and to feed it to a signal transmission connection between the antenna unit and the receiving unit, with the functional monitoring unit determining electrical characteristics and/or reflection characteristics of the signal transmission connection from a reflected component of the monitoring signal.

Furthermore, the functional monitoring unit may be designed to determine the impedance and/or the operating loss of the signal transmission connection between the antenna unit and the receiving unit.

The functional monitoring unit may be designed to determine reflection characteristics and/or electrical characteristics of the signal transmission connection between the antenna unit and the receiving unit by means of time domain reflectometry.

In one preferred variant of the invention, the toll system may be designed, when a malfunction in the antenna unit is identified, to produce an appropriate information signal, and to display this on the vehicle.

The invention together with further advantages will be explained in more detail in the following text with reference to a number of non-restrictive exemplary embodiments which are illustrated in the drawing, in which, schematically:

Figure 1 shows a toll system according to the invention;

Figure 2 shows a toll-payment apparatus with an antenna unit and a functional monitoring unit according to a first variant of the invention; and

Figure 3 shows a toll-payment apparatus with an antenna unit and a functional monitoring unit according to a second variant of the invention.

As is shown in Figure 1, a toll system SYS according to the invention has a position determination system POS, for example a satellite-based position determination system such as GPS, or some other position determination system based on radio transmission, for example based on a GSM network.

In order to determine the position of a vehicle FAR and to make a toll payment on the basis of its position coordinates, the vehicle has a toll-payment unit EIN which has an antenna unit ANE which is designed to be able to receive position determination signals PES from the position determination system POS. In order to simplify the illustration, only those elements which are significant to the invention are shown in the toll-payment unit EIN, specifically the antenna unit ANE and the receiving unit EMP. It is self-evident that further elements, such as a controller for calculation of position coordinates of the vehicle FAR from the received position determination data PED, etc, will

also be provided in the toll-payment unit EIN. Moreover, for the purposes of this document, the expression "toll-payment unit" means a functional unit, which may be physically distributed around the vehicle FAR.

The antenna unit ANE is connected to a receiving unit EMP for the toll-payment unit EIN via a signal transmission connection VER, for example an antenna cable. In the situation where the position determination system POS is the GPS system, the toll-payment unit EIN may have a GPS module with an appropriate receiving unit.

As is shown in Figure 2, in order to check the operation of the antenna unit ANE and/or of the signal transmission connection VER between the antenna unit ANE and the

receiving unit EMP, a monitoring signal SIG may be transmitted from the position determination system POS as pilot signal, for example in the form of a direct current or alternating current, to the toll-payment unit EIN, and may be fed to the antenna unit ANE. If the position determination system POS is the GPS system, then the pilot signal may also be transmitted in L band, as used for the GPS signal. If a functional monitoring unit FKE, for example an appropriately programmed signal processor, detects the presence or absence of this pilot signal at the receiver EMP or at the antenna unit ANE, it is easily possible to identify an interruption in the signal transmission connection VER between the antenna unit ANE and the receiver EMP for the toll-payment unit EIN, in which case the monitoring signal SIG may be produced at time intervals which can be predetermined.

Another variant of the invention provides for the monitoring signal SIG to be generated by a vehicle-mounted signal generator GEN or by a monitoring point ENF on the road (Figure 1), in which case a transmitter SEN may be provided to transmit the signal SIG to the antenna unit ANE. In response to this, the signal SIG may be transmitted via the signal transmission connection VER from the antenna unit ANE to the receiving unit EMP. At the end of the signal transmission connection VER which is associated with the receiving unit EMP, the functional monitoring unit FKE can detect the presence of the signal SIG and, if the signal SIG is absent, the functional monitoring unit FKE can generate an information signal. This information signal may be transmitted to an output unit, for example a light-emitting diode array, which displays a visual pattern (which is intended for this situation) on the vehicle FAR when an information signal is present.

A further variant of the invention as shown in Figure 3 provides for the monitoring signal SIG to be fed from the functional monitoring unit FKE to the signal transmission connection VER, with the electrical characteristics of the signal transmission connection being determined. In this case, the expression electrical characteristics means variables such as the impedance etc. In the embodiment mentioned above, the functional monitoring unit FKE may have its own signal generator. It is, of course, also possible for the signal generator to be physically separated from the functional monitoring unit FKE. In the following text, the expression functional monitoring unit FKE means a unit comprising a process controller for carrying out the method according to the invention, and a signal generator. The functional monitoring unit FKE may also be in integrated form, as a chip.

If the load on the antenna end of the signal transmission connection VER can differ from the impedance of the signal transmission connection VER, this can lead to reflections of the monitoring signal SIG which is fed to it. The quality of this transmission system can be described by the ratio of the reflected component REF of the monitoring signal SIG to the monitoring signal SIG which is emitted from the functional monitoring unit FKE. This ratio is referred to as the voltage reflection coefficient r, and depends on the impedance of the transmission line as defined by the following equation:

$$r = \frac{SIG}{REF} = \frac{Z_L - Z_0}{Z_L - Z_0}$$

If, by way of example, the monitoring signal SIG is produced in the form of a continuous sine-wave voltage, and the impedance Z_L of the antenna unit ANE is not the same as the impedance Z_0 of the signal transmission connection VER, then the magnitude of the monitoring signal SIG will fluctuate cyclically between a maximum value and a minimum value. This fluctuation, the standing wave, is caused by the phase relationship between the wave that is fed in and the reflected wave. The ratio between the maximum and minimum values of this voltage is the voltage standing wave ratio σ, and depends on the reflection coefficient r as defined by the following equation:

$$\sigma = \frac{1 + |r|}{1 \quad |r|}$$

Furthermore, the operating loss α, which is the logarithmic measure of the reflection coefficient r, is defined by the following formula:

$$\alpha = -20\log(r)$$

If there is a discrepancy which can be predetermined between the determined standing wave ratio σ for the signal transmission connection VER or the reflection coefficient r, and/or the operating loss α of the signal transmission connection VER, from nominal values which can be predetermined, then the signal transmission connection VER between the antenna unit ANE and the receiving unit EMP may be classified as being faulty, and a malfunction of the antenna unit ANE may be diagnosed.

Time domain reflectometry has been found to be particularly suitable for functional monitoring of the antenna unit ANE. In this case, the functional monitoring unit FKE can feed the monitoring signal SIG to the signal transmission connection VER to be checked, for example in the form of a positive voltage rise. The monitoring signal SIG moves along the transmission line. If the impedance of the antenna unit ANE corresponds the characteristic impedance of the transmission line, no signal will be reflected at the junction between the signal transmission line VER and the antenna unit ANE. However, if there is a mismatch at the antenna unit, part of the input voltage will be reflected. The reflected component REF of the monitoring signal SIG can easily be identified by the functional monitoring unit FKE, since it occurs at a different time to the monitoring signal SIG. This time difference can be used to determine the length D of the transmission path between the functional monitoring unit FKE and the discontinuity. This length D is calculated as follows:

$$D = v_\rho \frac{T}{2} = \frac{v_\rho T}{2}$$

where v_p is the propagation velocity of the monitoring signal SIG, and T is the delay time from the functional monitoring unit FKE to the fault location and back. The propagation velocity v_p can be determined experimentally using a cable of known length and of the same type. The fault location can be located unambiguously from knowledge of the propagation velocity v_p as well as the measured time difference between the monitoring signal SIG being fed and detection of the reflected component REF.

The nature and the magnitude of the mismatch can be determined from the form of the reflected component REF

- the reflected wave. As is known, knowledge of the monitoring signal SIG and of the reflected component REF, as measured by the functional monitoring unit FKE, allows the load impedance Z_L to be determined as function of the impedance Z_0 of the signal transmission connection VER, or vice versa - in this context, see, for example: "Dieter Dahlmeyer; Theorie der Zeitbereichsreflektometrie [Theory of time domain reflectometry], Parts 1, 2; elektronik industrie 2 [Electronics Industry 2] 2-2001; 3-2001".

One positive feature of the invention is that any manipulation of the antenna unit ANE can be identified directly since, in consequence, the impedance of the antenna unit ANE may change, so that the reflected component REF of the monitoring signal SIG may also change. The change causing the fault can be identified by suitable choice of limit values or comparison with system-typical reference values. A further advantage of the invention is that any malfunction of the antenna unit ANE

can be identified with little effort, in which case an information signal can be produced when an antenna malfunction is identified, and can be identified by a monitoring point external to the vehicle as the vehicle passes it.

NEW PATENT CLAIMS

1. A method for automatic functional monitoring of an antenna unit (ANE) for a vehicle-mounted toll-payment unit (EIN) for an electronic toll system (SYS), having a position determination system (POS), with the toll-payment unit (EIN) having a receiving unit (EMP) which is connected to the antenna unit (ANE), and the antenna unit (ANE) being designed to receive position determination signals (PES),
characterized in that
at least one monitoring signal (SIG), which interacts with the antenna unit (ANE), is produced, is fed to the toll-payment unit (EIN), and the operation of the antenna unit (ANE) being is checked on the basis of the monitoring signal (SIG), and in which case the monitoring signal (SIG) is produced as a pilot signal, is fed to the antenna unit (ANE), and the presence of the monitoring signal (SIG) is detected at the receiving unit (EMP).

2. The method as claimed in claim 1, characterized in that the monitoring signal (SIG) is transmitted together with the position determination signal (PES).

3. The method as claimed in one of claims 1 or 2, characterized in that the monitoring signal (SIG) is produced at time intervals which can be predetermined.

4. The method as claimed in one of claims 1 to 3, characterized in that the monitoring signal (SIG) is produced on board the vehicle (FAR).

5. The method as claimed in one of claims 1 to 4, characterized in that the monitoring signal (SIG) is produced by a vehicle-mounted functional monitoring unit

(FKE) which is connected to the toll-payment unit (EIN), and is fed to a signal transmission connection (VER) between the antenna unit (ANE) and the receiving unit (EMP), with the functional monitoring unit (FKV) determining electrical characteristics and/or reflection characteristics of the signal transmission connection (VER) from a reflected component (REF) of the monitoring signal (SIG).

6. The method as claimed in claim 5, characterized in that the monitoring signal (SIG) is used to determine values for electrical characteristics and/or reflection characteristics of the

signal transmission connection (VER), and these values are compared with nominal values for these characteristics.

7. The method as claimed in claim 5 or 6, characterized in that the impedance of the signal transmission connection (VER) is determined.

8. The method as claimed in one of claims 5 to 7, characterized in that the operating loss of the signal transmission connection (VER) between the antenna unit (ANE) and the receiving unit (EMP) is determined.

9. The method as claimed in one of claims 5 to 8, characterized in that the reflection characteristics and/or the electrical characteristics of the signal transmission connection (VER) between the antenna unit (ANE) and the receiving unit (EMP) are determined by means of time domain reflectometry.

10. The method as claimed in claims 1 to 9, characterized in that, when a malfunction is identified in the antenna unit (ANE), an appropriate information signal is produced and is displayed on the vehicle (FAR).

11. A toll system (SYS) for electronic toll payment having a position determination system (POS) and a vehicle-mounted toll-payment unit (EIN), which has an antenna unit (ANE) and a receiving unit (EMP) which is connected to the antenna unit (ANE), with the antenna unit (ANE) being designed to receive position determination signals (PES), characterized in that the toll system (SYS) is designed, for automatic functional monitoring of the antenna unit (ANE), to produce at least one monitoring signal (SIG) which interacts with the

antenna unit, to feed this to the toll-payment unit (EIN), and to use the monitoring signal (SIG) to check the operation of the antenna unit (ANE), and in that the toll system is furthermore designed to produce the monitoring signal (SIG) as a pilot signal, to feed the monitoring signal (SIG) to the antenna unit (ANE), and to detect the presence of the monitoring signal (SIG) at the receiver (EMP).

12. The toll system as claimed in claim 11, characterized in that the toll system is designed to transmit the monitoring signal (SIG) together with the position determination signal (PES).

13. The toll system as claimed in claim 11 or 12, characterized in that the toll system is designed to produce the monitoring signal (SIG) at time intervals which can be predetermined.

14. The toll system as claimed in one of claims 11 to 13, characterized in that a signal generator (GEN) is provided on board the vehicle (FAR) in order to produce the monitoring signal (SIG).

15. The toll system as claimed in one of claims 11 to 14, characterized in that a functional monitoring unit (FKE) which is connected to the toll-payment unit (EIN) is provided on board the vehicle (FAR) and is designed to produce the monitoring signal (SIG) and to feed it to a signal transmission connection (VER) between the antenna unit (ANE) and the receiving unit (EMP), with the functional monitoring unit (FKE) furthermore being designed to determine electrical characteristics and/or reflection characteristics of the signal transmission connection (VER) from a reflected component (REF) of the monitoring signal (SIG).

16. The toll system as claimed in claim 15, characterized in that the functional monitoring unit (FKE) is designed to use the monitoring signal (SIG) to determine values for electrical characteristics and/or reflection characteristics of the signal transmission connection (VER), and to compare these characteristics with nominal values for these characteristics.

17. The toll system as claimed in claim 15 or 16, characterized in that the functional monitoring unit (FKE) is designed to determine the impedance of the signal transmission connection (VER).

18. The toll system as claimed in one of claims 15 to 17, characterized in that the functional monitoring unit (FKE) is designed to determine the operating loss of the signal transmission connection (VER) between the antenna unit (ANE) and the receiving unit (EMP).

19. The toll system as claimed in one of claims 15 to 18, characterized in that the functional monitoring unit (FKE) is designed to determine the reflection characteristics of the signal transmission connection (VER) between the antenna unit (ANE) and the receiving

unit (EMP), and/or to determine the electrical characteristics of the antenna unit (ANE), by means of time domain reflectometry.

20. The toll system as claimed in one of claims 11 to 19, characterized in that the toll system is designed, when a malfunction in the antenna unit (ANE) is identified, to produce an appropriate information signal, and to display this on the vehicle (FAR).

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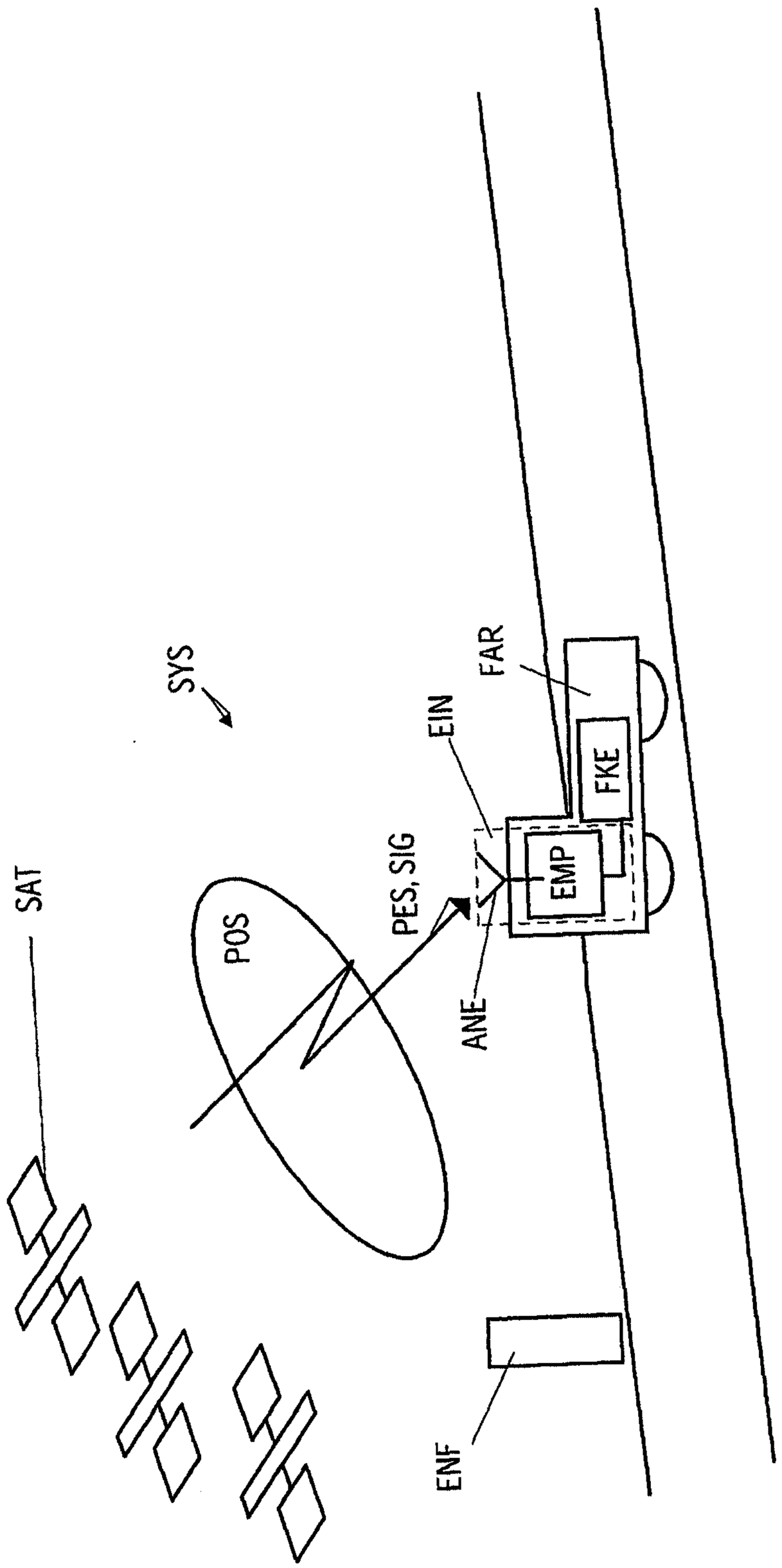


Fig. 1

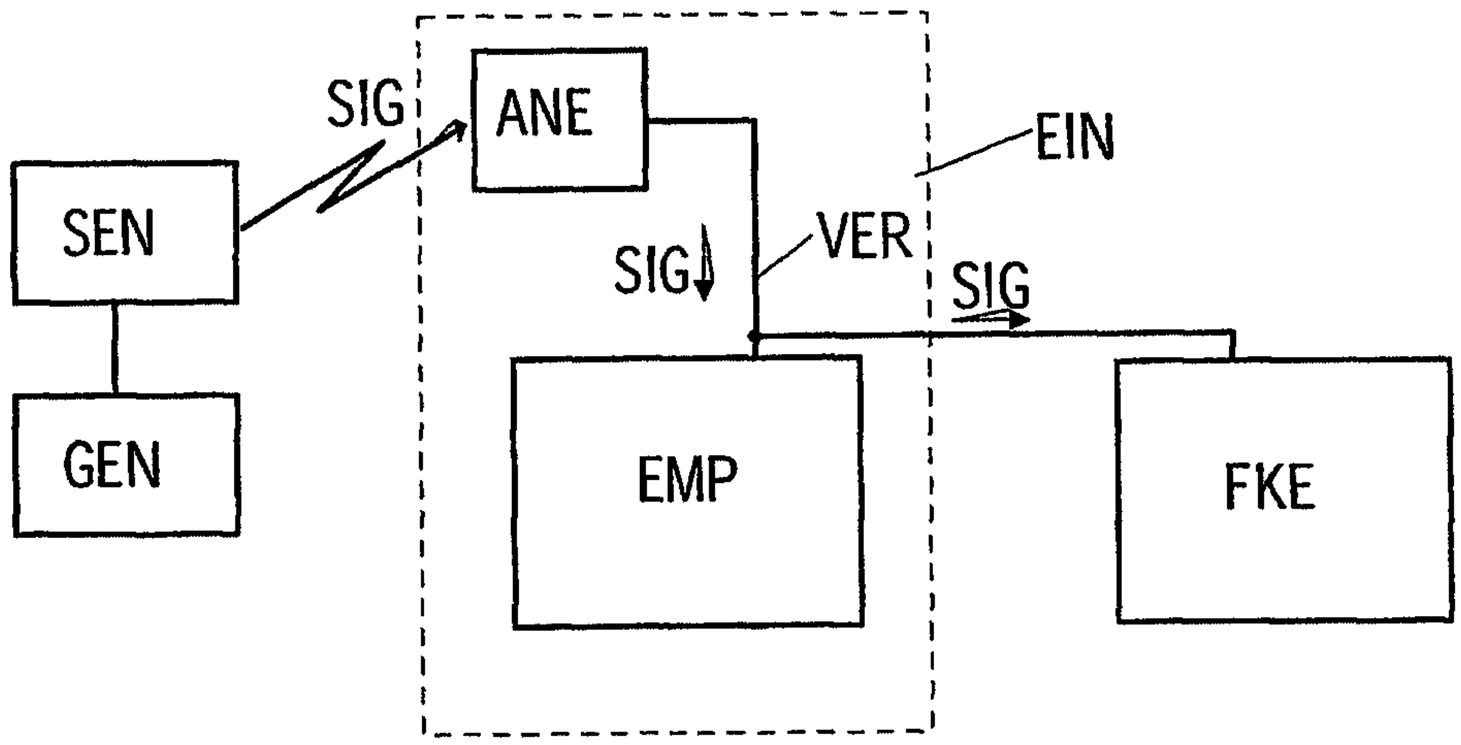

SIG
ANE
EIN
SEN
SIG
VER
SIG
GEN
EMP
FKE

Fig. 2

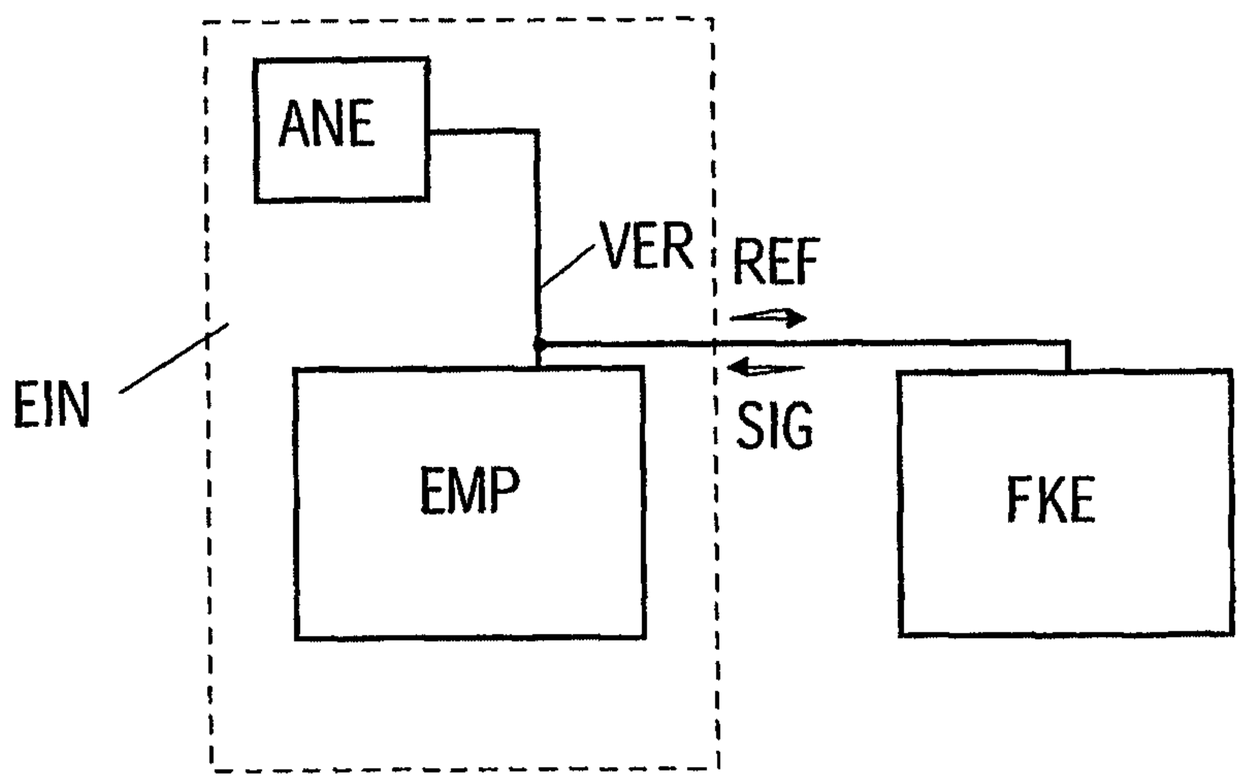
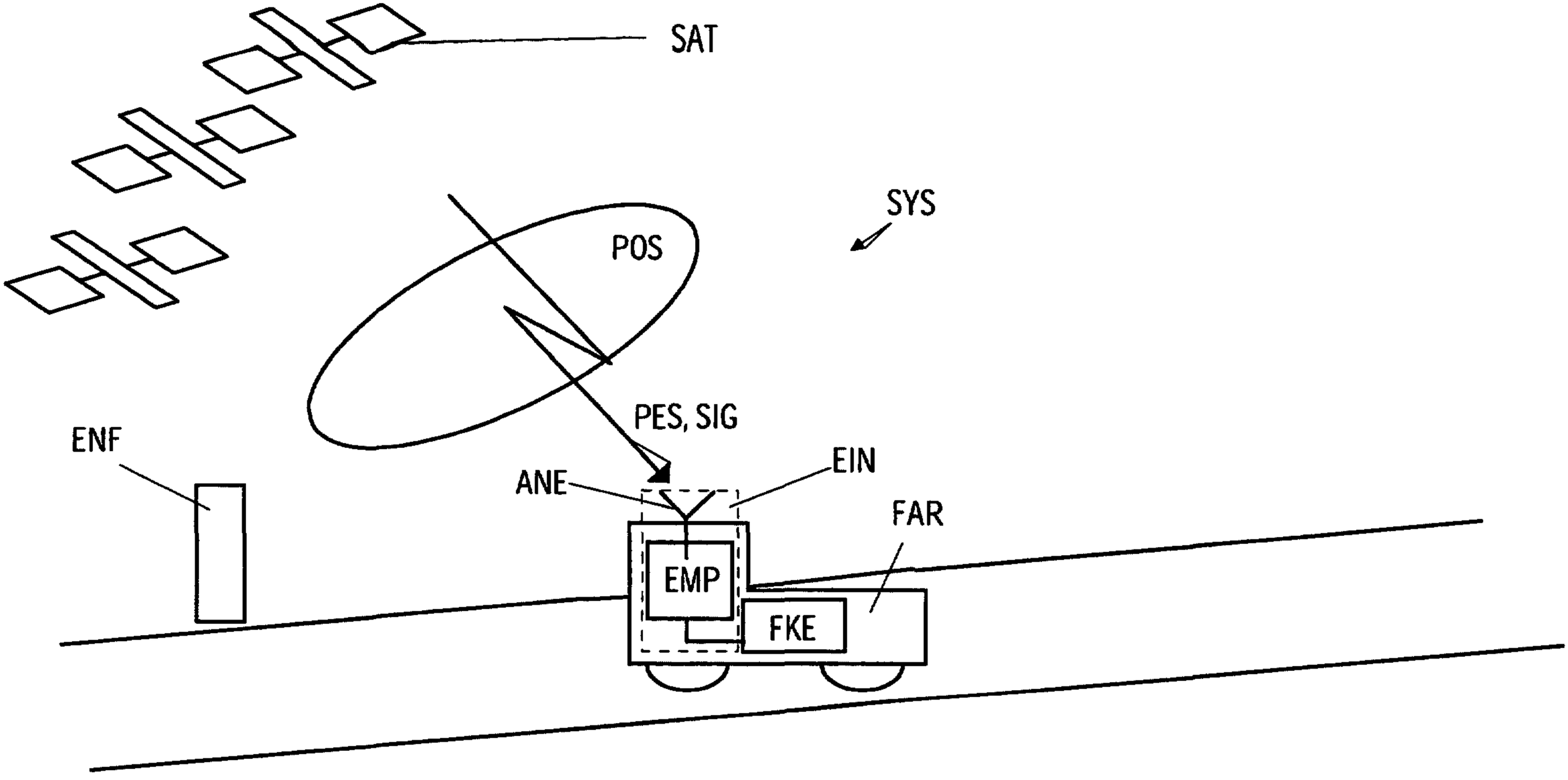

ANE
VER
REF
EIN
SIG
EMP
FKE

Fig. 3


SAT
SYS
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ENF
ANE
EIN
FAR
EMP
FKE