

MOBILE OBJECT IDENTIFICATION DEVICE

CROSS REFERENCE TO RELATED APPLICATION

The present application is based on and claims priority
5 from Japanese Patent Application No. Hei 6-168257 filed on July
20, 1994, the contents of which are incorporated herein by
reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

The present invention relates to a mobile object
identification device having an antenna located at a station and
a responder unit which is mounted on a mobile object, and more
particularly relates to a device in which an interrogatory
15 signal-wave is transmitted from the antenna to the responder unit
of a mobile object in a communication area to identify the object
according to a responding signal transmitted from the responder.

2. Description of the Related Art

A toll collection system for a toll road is one of the
20 well known mobile object identification systems. The toll
collection system, as shown in Fig. 11, has an in-vehicle
responder unit 3 (hereinafter referred to as IU) disposed on the
windshield glass of an automobile 2 and an antenna 4 disposed
on a toll gate located at a predetermined station to communicate
25 with an IU 3.

A pilot signal-wave of a given frequency is transmitted
repeatedly by a control unit (not shown) from the antenna 4 to

a communication area Sd. When it receives a responding signal which is transmitted by the IU 3 of the automobile 2 passing through the communication area Sd in response to the pilot signal-wave, the control unit transmits interrogatory signal waves such as a read-command signal, a write-command signal and the like for the toll-collection and receives the responding signals corresponding thereto.

The IU 3 does not generate a radio wave signal by itself but the antenna 4 transmits the pilot signal-wave or the interrogatory signal-wave and subsequently an unmodulated-carrier radio-wave. The IU 3 receives the carrier radio-wave and modulates it with a responding signal and responds to the antenna 4 by reflection of the carrier radio-wave. In other words, the IU 3 is not required to have an oscillating circuit or an electric power source, resulting in a simple, compact and inexpensive IU 3 as well as power saving of the automobile .

At the side of the antenna 4 which receives the responding signal, toll-due amount and/or the current balance thereof are calculated according to the type of the automobile and toll collection data. Thus, the driver is not required to stop his automobile 2 for exchanging a card or money each time he uses the toll road, so that congestion at the toll gate is relieved and also the troublesome exchange of the card or money can be omitted. In addition, people working in the toll gate may not be exposed to the exhaust gases of automobiles.

However, in the above system, since an unmodulated carrier-radio-wave-signal transmitted from the antenna 4 is

transmitted again by the reflection toward the antenna 4 after
it is modulated with a responding signal, it becomes attenuated
before it is received by the antenna 4 and, therefore, the
responding-communication area S_u (uplink area), where the
5 responding signal-wave-signal transmitted by the IU 3 can be
received by the antenna 4 become narrower than the communication
area S_d (downlink) where the pilot signal-wave and the
interrogatory signal-wave transmitted by the antenna 4 can be
received by the IU3.

10 That is, although the IU 3 of the automobile 2 in the
responding-communication area S_u shown in Fig. 11 can transmit
the responding signal-wave to the antenna 4 in response to the
pilot signal-wave, an IU 3a of another automobile in the
communication area S_d indicated by a broken line is out of the
15 responding-communication area S_u and cannot transmit the
responding signal-wave to the antenna 4 in response to the pilot
signal-wave. Therefore, the substantial communication area is the
communication area S_u , which is also the uplink area.

As shown in Fig. 12 for example, if a plurality of
20 antennas 6 and 7 are used to cover a broader communication area,
the following problems arise.

The antennas 6 and 7 are set side by side and the uplink
areas are formed as the communication areas S_{u1} and S_{u2} as shown
in Fig. 12, and the communication areas are arranged to form an
25 overlapping area S_{up} at an adjacent portion thereof, thereby
avoiding failure in communication with the automobile passing
through the portion between the communication areas S_{u1} and S_{u2} .

The antennas 6 and 7 are arranged to output the radio wave signals of different frequencies at different timings so that the communication with the antenna 6, for instance, is ensured even if an automobile passing through the intervening portion between the areas Su1 and Su2 and the antenna 6 receives the pilot signal-wave first, since the IU 3 composes the responding signal and modulates the unmodulated carrier radio-wave received from the antenna 6 to retransmit and the antenna 7 does not respond to the pilot signal-wave.

10 However, in order to provide the communication areas Su1 and Su2 in which the responding signal of the IU 3 can be transmitted, the broader downlink areas Sd1 and Sd2 must be formed as indicated by broken lines in Fig. 12. Therefore, if two automobiles 2b and 2c as shown in Fig. 12 exist in the communication area Su 1, and IU 3 of the automobile 2c is out of the area Su 2, however, within the downlink area Sd 2 and if the antenna 7 receives the pilot signal-wave first, the responding signal-wave of the automobile 2c is not received by the antenna 7 but received by the antenna 6. On the other hand, since the other automobile 2b exists in the communication area Su 1, the IU 3b thereof transmits a responding signal-wave in response to the pilot signal-wave coming from the antenna 6, and thereby interferes with the responding signal-wave of the IU 3c, causing communication troubles.

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SUMMARY OF THE INVENTION

The present invention is made in view of the above

mentioned circumstances, and has a main object of providing a mobile object identification device in which a communication area formed by an antenna disposed on a station and another communication area formed by a responder unit (or In Vehicle Unit, hereinafter referred to as the IU) mounted on an mobile object become substantially the same in their shapes and sizes, thereby preventing communication failure.

Another object of the present invention is to provide a mobile object identification device which includes the IU mounted on a mobile object for modulating a carrier radio-wave received from the outside with related data and transmitting it back as a responding signal-wave, antenna control means for transmitting a carrier radio-wave and receiving the responding signal-wave through an antenna to identify the automobile; and means for decreasing output power of the antenna to a prescribed level during the communication so that transmitting area (or downlink area) and the receiving area (uplink area) of the antenna and IU may coincide with each other during the communication.

A further object of the present invention is to provide a mobile object identification device which includes an IU mounted on an automobile for modulating a carrier radio-wave received from the outside with a related data and transmitting it back as a call-back signal-wave when receiving a call signal-wave from the outside and for modulating another carrier radio-wave with an answering data and transmitting it back as an answering signal-wave when receiving an interrogatory signal-wave, antenna

control means for the transmitting the call signal-wave and the carrier radio-wave when receiving the call-back signal-wave and for transmitting an interrogatory signal-wave and carrier radio-wave when receiving said answering signal and for identifying the automobile, and area setting means for decreasing output power of the antenna to a prescribed level during the call signal-wave is transmitted.

A still further object of the invention is to provide a mobile object identification device which includes, in addition to the above structure plurality of antennas disposed so as to transmit and receive radio wave signals of different frequencies assigned in a given frequency domain of the IU to and from a plurality of the communication areas overlapping one another, and the control means providing different timings of its output signals corresponding to the communication areas of the antennas.

Thus, the antenna installed on the toll gate can receive the responding signal in the antenna receiving area which substantially coincides with the antenna transmitting area when the responder unit receives the communication signal in the antenna transmitting area, thereby ensuring the reliable communication with the IU without communication failure.

When the IU mounted on an automobile enters the transmitting area and receives a call signal-wave, it composes a call-back signal-wave by modulating the received carrier radio-wave with a call back data and transmit the call-back signal-wave to the outside. The level of the call-back signal-wave at the moment of transmission is lower than the level of the

unmodulated-carrier-radio-wave generated by the control means since the call-back signal-wave only utilizes the unmodulated-carrier-radio-wave transmitted from an outside antenna. Therefore, the area setting means decreases the antenna output power to a prescribed level to narrow the transmitting area when the control means transmits a communication signal such as a call signal-wave or an interrogatory signal-wave and restores the antenna output power to its original level when the control means transmits the unmodulated-carrier-radio-wave.

When the control means receives the call-back signal-wave, the antenna transmits the interrogatory signal-wave and subsequently the unmodulated-carrier-radio-wave. When the responder unit receives the interrogatory signal-wave, it composes the answering data and modulates the subsequently-received-unmodulated-carrier-radio-wave with the answering data and transmits it as an answering signal to the antenna. When the antenna completes the communication, it transmits the call signal-wave again.

As a result, when the IU receives the call signal-wave in the transmitting area, the antenna can receive the call-back signal-wave in the receiving area which substantially coincides with the transmitting area so that reliable communication is ensured without fail. Further, when one IU in the communication area receives the interrogatory signal-wave and other responder units in the same communication area do not receive the call signal-wave, the interrogatory signal-wave is transmitted only to the one IU which has received the call signal-wave and only

its call-back signal-wave is received by the antenna, and the call signal-wave for the other IU is subsequently transmitted to achieve the communication successively.

5 Since the control means outputs its signals at different timings to a plurality of antennas which has transmitting areas overlapping one another, when an automobile exists in the overlapping communication area, its IU receives either one of the communication signals from the antennas.

10 Since the communication signals and the unmodulated-carrier-radio-waves transmitted from the different antennas have different frequencies, the communication with only one antenna is ensured. Thus, reliable communication covering a broad area without leaving dull area is provided.

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BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and characteristics of the present invention as well as the functions of related parts of the present invention will become clear from a study of the following detailed description, the appended claims and the drawings. In
20 the drawings:

Fig. 1 is a block diagram illustrating a mobile object identification device according to an embodiment of the present invention;

25 Fig. 2 is an overall perspective view illustrating the device according to the embodiment;

Fig. 3 is an overall schematic view of the device according to the embodiment;

Fig. 4 is a chart illustrating frequency characteristics of an IU and antennas of the device according to the embodiment;

Fig. 5A, 5B, 5C, 5D and 5E are timing charts of an interrogatory-data signal of the device according to the
5 embodiment;

Fig. 6 is a flow chart of a control program of an antenna of the device according to the embodiment;

Fig. 7 is a flow chart of a control program of an IU of the device according to the embodiment;

10 Fig. 8 is a time chart showing the timings of the communication between the antenna and the IU according to the embodiment;

Fig. 9 is an explanatory chart illustrating the communication when two automobiles enter a communication area;

15 Fig. 10 is a chart corresponding to Fig. 8 showing the communication timings when two automobiles enter a communication area;

Fig. 11 is a schematic view illustrating a communication area in a conventional system; and

20 Fig. 12 is an explanatory schematic view when a communication trouble is caused.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

25 A toll collecting system for a toll road according to an embodiment of the present invention is described with reference to Figs, 1 through 10 next.

An overall perspective view of a toll road 20 is

illustrated in Fig. 2. The toll road 20 has five passing lanes 21a through 21e. Each of two automobiles 22, which is a kind of the mobile objects, is equipped with an IU (In-vehicle Unit or responding unit) 23 which is disposed on an upper central portion of the windshield glass of each of the automobile 22 when it runs on the toll road as shown in Fig. 3. A gate 24 is built to cross the toll road 20 and is equipped with a plurality (in this case, five) of antenna units 25a through 25e above the lanes 21a through 21e respectively. Each of the five antennas 25a through 25e faces the road surface obliquely downward. Communication areas 25a through 26e thereof are arranged so that the adjacent ones overlap partly with each other to form overlapping-communication areas 27a through 27d as shown in Fig. 3.

The antenna units 25a through 25e are connected to an antenna controller 28 as shown in Fig. 1. The antenna controller 28 controls the antennas 25a through 25e to transmit and receive signals and to exchange data between a host computer and a signal-processing-unit 29 shown in Fig. 3.

Now, the structure of the antenna units 25a through 25e is described with reference to Fig. 1.

A transmitting and receiving antenna 30 is an array antenna which is a plurality of patch antennas composed of micro-strip lines formed on a printed board in order to increase the directivity of the antenna and the communication distance. A modulating circuit 31 modulates a carrier radio-wave having the frequency f_1 which is generated by an oscillator 32 with an interrogatory data-signal received from the controller 28 and

generates a modulated-carrier-wave as an interrogatory signal-wave S_k on the antenna 30 through a circulator 33. The frequency f_1 of the carrier radio-wave generated by the oscillator 32 is one in the assigned frequency band, for example, 2.45 GHz. The
5 antenna 32 receives only a limited range of the radio wave frequency f_1 generated by the oscillator 32.

A signal receiving circuit 34 (hereinafter referred to as the receiving circuit) for signal-processing such as demodulation is connected to a mixer 35. The mixer 35 is supplied with the
10 carrier-radio-wave from the oscillator 32 and is also supplied with a responding signal-wave (which is a carrier-radio-wave modulated with a responding data signal) coming from the antenna 30 through the circulator 33. The carrier-radio-wave and the responding signal-wave are mixed by the mixer 35 and supplied to
15 the receiving circuit 34. The receiving circuit 34 demodulates the mixed signal-wave and obtains the responding data signal and send it to the controller 28.

Other antenna units 25b through 25e are the same in the structure as the antenna unit 25a except for their frequencies.
20 That is, the frequency f_1 is generated by the oscillator 32 for the antenna units 25a, and the frequencies f_2 through f_5 for the antenna units 25b through 25e are generated in a narrow frequency band so as not to overlap with one another. These oscillation frequencies are assigned in the previously mentioned fixed
25 frequency band (2.45 GHz band) and the frequencies for the adjacent antenna units are assigned to differ from each other as much as possible.

In the antenna controller 28, a control circuit 36 includes a CPU (not shown) and is connected to respective modulating circuits 31, receiving circuits 34 and the oscillator 32 of the antenna units 25a through 25e. The antenna controller 28 executes
5 a program which is described later and generates an interrogatory data-signal to the modulating circuit 31 at a timing to be described later, receives a responding data-signal through the receiving circuit 32 and decreases the output power of the oscillator 32 to a prescribed level at a timing of outputting a
10 pilot signal-wave S_p to be explained later. The control circuit 36 is connected through an interface circuit 37 to the signal-processing-circuit 29 which is previously described (see Fig. 3). A power supplying circuit 38 converts an AC current supplied from an electric source (not shown) to a DC current and supplies it
15 to the control circuit 36 and the interface circuit 37 as well as the respective antenna units 36a through 36e.

In the IU 23, an antenna 39 is a micro-strip-antenna formed on a printed board and is arranged to receive radio waves in a broad frequency band as shown by a broken line in Fig. 4.
20 That is, it can receive all the frequencies f_1 through f_5 of the interrogatory signal-waves S_k transmitted from the respective antenna units 25a through 25e.

The control circuit 40 includes a CPU, a ROM and a RAM, and generates responding data-signals for a call-back signal-wave
25 (or pilot-responding signal-wave) and answering signal-wave (or interrogatory-responding signal-wave) when receiving a pilot signal-wave S_p or an interrogatory signal-wave S_k from the

outside. In the meantime, the pilot signal-wave S_p causes the CPU of the control circuit 40 to start its operation and interrogates an automobile about its identification code, and the interrogatory signal-wave S_k causes the CPU to read data stored in the ROM and/or RAM of the control circuit 40 or to write data to the RAM for the toll collection. The control circuit 40 is connected to the antenna 39 through a transmitting circuit 41 and through a receiving circuit 42.

The transmitting circuit 41 modulates an unmodulated-carrier-radio-wave which is received from the antenna 39 with a responding signal such as the call-back signal-wave and transmits the modulated-carrier-wave as a responding signal-wave such as the call-back signal-wave A_p . The receiving circuit 42 demodulates the interrogatory signal-wave S_k received from the antenna 39 to obtain an interrogatory data-signal and sends it to the control circuit 40. The control circuit 40 is connected to a data memory 43 which is a non-volatile read-write memory. The control circuit 40 does not transmit any signal-wave even if it receives the interrogatory signal-wave S_k until it receives the pilot signal-wave S_p . After the control circuit 40 has started its communication with one of the antenna units 25a through 25e, it will not start communication with another. When a series of toll collection process has been carried, the control circuit 40 stops its communication and does not start its communication after a while or after running a given distance. A battery 44 energizes respective circuits in the IU 23a.

The operation of the above embodiment is described with

reference to Fig. 5 through Fig.10 next. The control circuit 36 of the antenna controller 28 generates communication data-signals, in this case, a pilot data-signal which is described later and interrogatory data-signal and supplies them to the
5 respective antenna units 25a through 25e at timings shown in Fig. 5. The antenna controller 28 sends the communication data-signals repeatedly to odd-ordered antenna units 25a, 25c and 25e at the same timing during each cycle time T_1 , and to even-ordered
10 antennas 25b and 25d during each the same cycle time T_1 but a time T_2 (e.g. $T_1/2$) later than the former.

In the respective antenna units 25a through 25e, the modulation circuit 31 modulates the carrier-radio-wave with the communication data-signals and transmits the communication
15 signal-waves to the respective communication areas 26a through 26e by the antennas 30.

In this case, there are two kinds of the communication data-signals, the pilot data-signal and the interrogatory data-signal. They are generated repeatedly during a period t_a within
20 the output cycle time T_1 and the remaining cycle time t_b ($t_a + t_b = T_1$) is set to receive the responding signal-waves or data-signals (which are obtained after the responding signal waves are demodulated). The output period t_a for the pilot data-signal and the interrogatory data-signal is arranged not to overlap with
25 those from the adjacent antenna units, for instance, antenna units 25a and 25b.

During the cycle time t_b ($t_b = T_1 - t_a$, as shown in Fig. 5) in which neither the communication data-signals are supplied

by the controller 28 nor the modulation is made by the modulating circuit 31, the unmodulated-carrier-radio-waves is generated by the oscillators 32 and is transmitted by the respective antenna units 25a through 25e to the respective communication areas 26a through 26e. That is, the respective antenna units 25a through 25e always transmit radio-waves which include the pilot signal-wave S_p (carrying the pilot data-signal) and the interrogatory signal-wave S_k (carrying the interrogatory data-signal) transmitted during the period t_a within the cycle time T_1 .

10 The output power level of the antennas 30 of the respective antenna units 25a through 25e is arranged so that the level of the pilot signal-wave S_p becomes L_1 and the level of the interrogatory signal-wave S_k and the unmodulated-carrier-radio-wave becomes L_2 which is a given level higher than the output power level of L_1 . The receiving and transmitting of the signal-waves by the antenna units 25a through 25e are controlled according to a communication program shown in Fig. 6 and the corresponding operations by the IU 23 are controlled according to a communication program shown in Fig. 7.

20 In other words, when the control circuit 36 starts to control the antenna units 25a through 25e according to the communication program after its initialization (step S1) shown in Fig. 6, the oscillator 32 sets the output level of the antenna 30 to L_1 (step S2), and, subsequently, pilot signal-wave S_p is transmitted (step S3). Then, the oscillator 32 sets the output level of the antenna 30 to L_2 ($L_2 > L_1$) (step S4) and the unmodulated-carrier-radio-wave is transmitted (step 4), and the

arrival of the call-back signal-wave Ap is waited for until the cycle time T1 terminates.

If the antenna units 25a through 25e have not receive the call-back signal-wave Ap during the cycle time T1, [NO] is
5 determined in a step S6 and the program returns to the step S2 and the steps S2 through S6 are repeated until the call-back signal-wave Ap is received, in other words, until the IU 23 comes into anyone of the communication areas 26a through 26e, and, if received, [YES] is determined. Then, the program takes
10 step S7 and the antenna units 25a through 25e transmit the interrogatory signal-wave Sk to read data for toll collection and else from the IU 23 (step S7). Thereafter, they transmit the unmodulated-carrier-radio-wave (step S8) and wait for receiving the interrogatory-responding-signal-wave (hereinafter referred
15 to as answering signal-wave) Ak from IU 23, and signal processing is executed if they receive it (step S9).

If data writing is necessary in addition to data reading, the antenna units 25a through 25e to transmit the interrogatory signal-wave Sk which includes data to be written into the IU 23
20 before the communication is completed. In this case, [NO] is determined in a step S10 and the program returns to the step S7. Then, the interrogatory signal-wave Sk is transmitted (step S7) and the program goes through the steps S8 and S9 to the step S10, where [YES] is determined and the communication is stopped when
25 the transmission of the interrogatory signal-wave is completed. Then, the program returns to the step S2 to repeat the above-described operations.

Since the output level L1 is set only while the pilot signal-wave Sp is being transmitted and the output level L2 is set while the interrogatory signal-wave Sk and the unmodulated-carrier-radio-wave are being transmitted, the communication area
5 26a through 26e of the pilot signal-wave Sp which can be received by the IU 23 substantially coincides with the communication areas of the call-back signal-wave Ap and the answering signal Ak which can be received by the antenna 30.

When the IU 23 is operated according to the communication
10 program shown in Fig. 7, an initialization is executed in a step T1, and it waits for the pilot signal-wave Sp (step T2). When it comes into any one of the communication areas 26a through 26e and receives (by the antenna 39) the pilot signal-wave Sp transmitted from the antenna units 25a through 25e, the signal-wave is
15 demodulated by the receiving circuit 42 and applied to the control circuit 40, and [YES] is determined to go to the next step T3. The IU 23 receives the unmodulated-carrier-radio-wave by the antenna 39 subsequently, and modulate it with the call-back data-signal outputted through the transmitting circuit 41,
20 and transmits the call-back signal-wave Ap which is the modulated-carrier-radio-wave (step T3). Thereafter, steps T4 and T5 are repeated until the interrogatory signal-wave Sk is received.

When the IU 23 receives the interrogatory signal-wave Sk
25 from any one of the antenna units 25a through 25e, signal processing for transmitting or writing data of the toll collection is carried according to the contents of the

interrogatory signal-wave S_k . If the data is to be memorized, the data are written into the data memory 43 by the control circuit 40, and if there are data to be read, the data are read from the data memory 43 (step T6). Thereafter, the answering signal-wave A_k is composed, in other words, the unmodulated-carrier-radio-wave is modulated (step T7). When the interrogatory signal-wave S_k does not include a termination signal of the communication, the IU 23 determines [NO] in the next step T8 and returns to the step T4 where it waits for the interrogatory signal-wave S_k again. On the other hand, when it includes the termination signal, the IU 23 determines [YES] and the termination of the communication is executed (step T9), and returns to the step T2.

If the IU 23 has not received the interrogatory signal-wave while the steps T4 and T5 are repeated in a given period, [YES] is determined in a step T5 and a communication error process is carried (step T10). As a result, the IU 23 returns to the step T2 and waits for the pilot signal-wave S_p again.

Although the step is not convenient in case of a system trouble, it ensures to receive the signals when the IU 23 passes the next gate.

If two automobiles 22a and 22b are passing on the respective lanes 21a and 21b and approaching the gate 24, and the IU 23a and the IU 23b, after a while, enter into the communication areas 26a and 26b while the pilot signal-wave S_p is transmitted to the respective communication areas 26a through 26e as shown in Fig. 3, the IU 23b receives the pilot signal-wave S_p first from the antenna unit 25b and transmits the call-back

signal-wave Ap and the answering signal-wave Ak in response to the interrogatory signal-wave Sk, and after a while the IU 23a receives the pilot signal-wave Sp from the antenna unit 25a and the same processes as above are carried thereafter.

5 Thus, when the automobiles 22a and 22b pass the gate 24, the data communication for the toll collection is carried automatically between the gate 24 and the IU 23a and IU 23b. Since the communication areas where the pilot signal-wave (transmitted from the antenna units 25a through 25e) can be received by the
10 IU 23a and IU 23b becomes almost the same as the communication areas where the IU 23a and the IU 23b can transmit the call-back signal-wave Ap, reliable communications are ensured.

 When the automobile 22b in Fig. 3 passed through the communication area 26b beforehand and then enters to the area
15 26a, the IU 23b transmits the call-back signal-wave Ap in response to the pilot signal-wave Sp from the antenna 25b but does not respond to the pilot signal-wave from the antenna 25a. That is, the IU 23b only communicates with the antenna unit 25b, and the IU 23a likewise only communicates with the antenna unit 25a. Since
20 the IU 23a and IU 23b do not start communications for a while or until a short-distance-running after the toll collection process has been completed, they do not transmit the call-back signal-wave Ap even if they receive the pilot signal-wave Sp from the antenna units 25a and 25b after the toll collection process has been
25 completed.

 A case where three automobiles 22c through 22e are passing the communication area 26a as shown in Figs. 9 and 10 is

described next. Fig. 9 shows the automobile 22c entering the communication area 26a earlier, the automobile 22d subsequently entering the communication area 26a, and the automobile 22e passing a downlink area 26ad outside the communication area 26a where signals other than the pilot signal-wave Sp (lower level signal-wave) of the antenna unit 25a may be received.

As shown in Fig. 10, the IU 23c of the automobile 22c, which has entered the communication area 26a earlier, receives the pilot signal-wave Sp from the antenna unit 25a and responds to the signal to start its communication. Although the automobile 22d enter the communication area 26a during the communication of the IU 23c, the IU 23d does not start its communication even if it receives the interrogatory signal-wave Sk since the antenna unit 25a is in communication with the IU 23c and the interrogatory signal-wave Sk is being transmitted.

When the communication between the IU 23c and the antenna unit 25a has been completed and the pilot signal-wave Sp is transmitted from the antenna unit 25a again, the IU 23c receives the signal-wave and starts the communication. Since the IU 23c has completed its communication at this moment, it neglects the pilot signal-wave Sp even if it subsequently receives the signal. Thus, the IU 23d solely communicates with the antenna unit 25a.

The IU 23e of the automobile 22e passing through the downlink area 26ad does not receive the pilot signal-wave Sp since it passes outside the communication area 26a, and the automobile 22e passes without communication even if it receives the interrogatory signal-wave Sk. The automobile 22e in practice,

however, passes the communication area 26b of the antenna unit 25b as shown in Fig. 3, and IU 23e receives the pilot signal-wave Sp from the antenna unit 25b and starts its communication.

When the IU 23 of the automobile enters a communication area 27a where the communication areas 26a and 26b of the antenna units 25a and 25b overlap with each other, the IU 23 receives the pilot signal-wave from either one of the antenna units 25a and 25b since the antenna units 25a and 25b transmit the pilot signal-wave Sp at different timings as stated before so as to ensure steady communication of the IU 23 with either one of the antenna units 25a and 25b.

Since the communication time is not shared by the antenna units 25a and 25b, it is not so much limited as compared to the ordinary time-sharing communication and can be secured sufficient even while the automobile is running at a high speed. Thus, the reliable communication with the antenna unit 25a or 25b and, consequently, the reliable identification can be achieved.

The present embodiment has the following effects.

First, when the antenna units 25a through 25e transmit the pilot signal-wave, the output level L1 is set to be lower than the output level L2 for other signals. As a result, when the IU 23 which has received the pilot signal-wave Sp in one of the communication areas 26a through 26e, it modulates subsequently the unmodulated-carrier-radio-wave which is received subsequently at an increased power level and transmit it as the call-back signal-wave to the corresponding antenna units without fail. Since the antenna units 25a through 25e transmit the interrogatory

signal-wave S_k at the higher output level L2, the IU 23 can receive the signal-wave without fail.

Since the communication timings for the pilot signal-wave S_p and for the interrogatory signal-wave between IU 23 and the antenna units 25a through 25e are separated so that IU 23 receives the interrogatory signal-wave S_k only after it receives the pilot signal-wave S_p , if one of the IUs 23 is receiving the interrogatory signal-wave S_k while running in one of the communication areas, another of the IUs 23 entering the same communication area will receive the pilot signal-wave S_p after the former communication completes. Thus, the communication may be achieved without interference of the two IUs 23.

Since the frequencies f_1 through f_5 of the oscillators 32 are assigned to a narrow frequency band and the controller 28 controls to shift the timing of the pilot signal-wave S_p of the adjacent antennas by a period T_2 , the respective antenna units 25a through 25e can communicate with the respective IUs 23 of the automobiles 22 without interference in a short time.

The modulating circuit 31 may be arranged to control the oscillator 32 to transmit the unmodulated-carrier-radio-wave automatically from the antenna units 25a through 25e whenever none of the pilot signal-wave S_p or interrogatory signal-wave S_k is transmitted.

The data memory 43 of the IU 23, which is integrated into a unit, may be separated as a detachable member such as a memory card or a prepaid card.

The communication may be completed by one time

interrogatory signal-wave by combining the pilot signal-wave Sp and the interrogatory signal-wave Sk.

5 The communication areas overlapping more than three may be provided without fail by setting different timings for the pilot signal-wave Sp and the interrogatory signal-wave Sk transmitted from the respective antenna units thereby to prevent the communication interference.

In the communication area which has no overlapping area, the same wave may be used.

10 The present invention for the toll collection system of the toll road may be applied to a system such as an operating system for an unmanned carrier which carries products in a plant, a production control system for controlling the production line of a plant, an access control system which controls people coming
15 in or going out of rooms or the like system.

In the foregoing discussion of the present invention, the invention has been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made to the specific embodiments of the present
20 invention without departing from the broader spirit and scope of the invention as set forth in the appended claims. Accordingly, the description of the present invention in this document is to be regarded in an illustrative, rather than a restrictive, sense.



What is claimed is:

1. A mobile object identification device for a communication area where information is exchanged between a mobile object and a station comprising:

an antenna control unit having an antenna disposed at said station for transmitting a communication signal -wave and an unmodulated carrier-radio-wave through an antenna toward said communication area and receiving a responding signal-wave from said communication area;

a responder unit mounted on said mobile object for transmitting said responding signal-wave when receiving said communication signal-wave and said unmodulated carrier-radio-wave subsequently, said responder unit including a receiving circuit receiving an unmodulated carrier-radio-wave from said communication area, a control circuit generating a responding data-signal, and a transmitting circuit modulating said unmodulated carrier-radio-wave with said responding data-signal and transmitting a modulated carrier-radio-wave as said responding signal-wave; and

means for decreasing output power of said antenna to a prescribed level while said antenna control unit is transmitting said communication signal.

2. A mobile object identification device claimed in claim 1 further comprising a gate for toll collection, wherein said antenna is disposed on said gate.



3. A mobile object identification device claimed in claim 2, wherein said antenna control unit comprises means for transmitting an interrogatory signal wave and said unmodulated carrier-radio-wave subsequently.

4. A mobile object identification device claimed in claim 3 further comprising a signal-processing-circuit for processing data for said toll collection when receiving said responding signal-wave.

5. A mobile object identification device claimed in claim 2, wherein said antenna control unit further comprises a plurality of antennas disposed on said gate.

6. A mobile object identification device claimed in claim 5, wherein said antenna control unit further comprises means for generating said carrier waves having different frequencies and assigning said carrier-radio-waves to said antennas corresponding to said communication areas overlapping with one another.

7. A mobile object identification device claimed in claim 5, wherein said means for generating said carrier-radio-waves having different frequencies further comprises circuit means for supplying said communication signal-waves at different timings to said antennas corresponding to those of said communication areas overlapping with one another.



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8. A mobile object identification device claimed in claim 4, wherein said responder unit includes a communication program which controls last said unit to stop communication for a given period after said toll collection process has been completed.

9. A mobile object identification device claimed in claim 4, wherein said responder unit includes a communication program which controls last said unit to stop communication until a given running distance after said toll collection process has been completed.

10. A mobile object identification device claimed in claim 2, wherein said antenna control unit comprises means for transmitting a pilot signal-wave and an unmodulated-carrier-radio-wave successively, and an interrogatory signal wave subsequent to receiving said responding signal-wave from said responder unit.

11. A mobile object identification device claimed in claim 10, wherein said responder unit includes a communication program which controls said unit to stop communication until it has received said pilot signal-wave.

12. A mobile object identification device claimed in claim 11, wherein said responder unit includes a communication program which controls said unit to prohibit communication with



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others when it has received a pilot signal-wave from one of said antennas.

13. A mobile object identification device claimed in claim 11, wherein said means for transmitting said pilot signal-wave and interrogatory signal wave transmit said pilot signal-wave at a power level lower than said interrogatory signal-wave.

14. A mobile object identification device claimed in claim 11, wherein said means for transmitting said unmodulated-carrier-radio-wave transmits said unmodulated carrier-radio-wave at the same power level as said interrogatory signal-wave.

FIG. 1

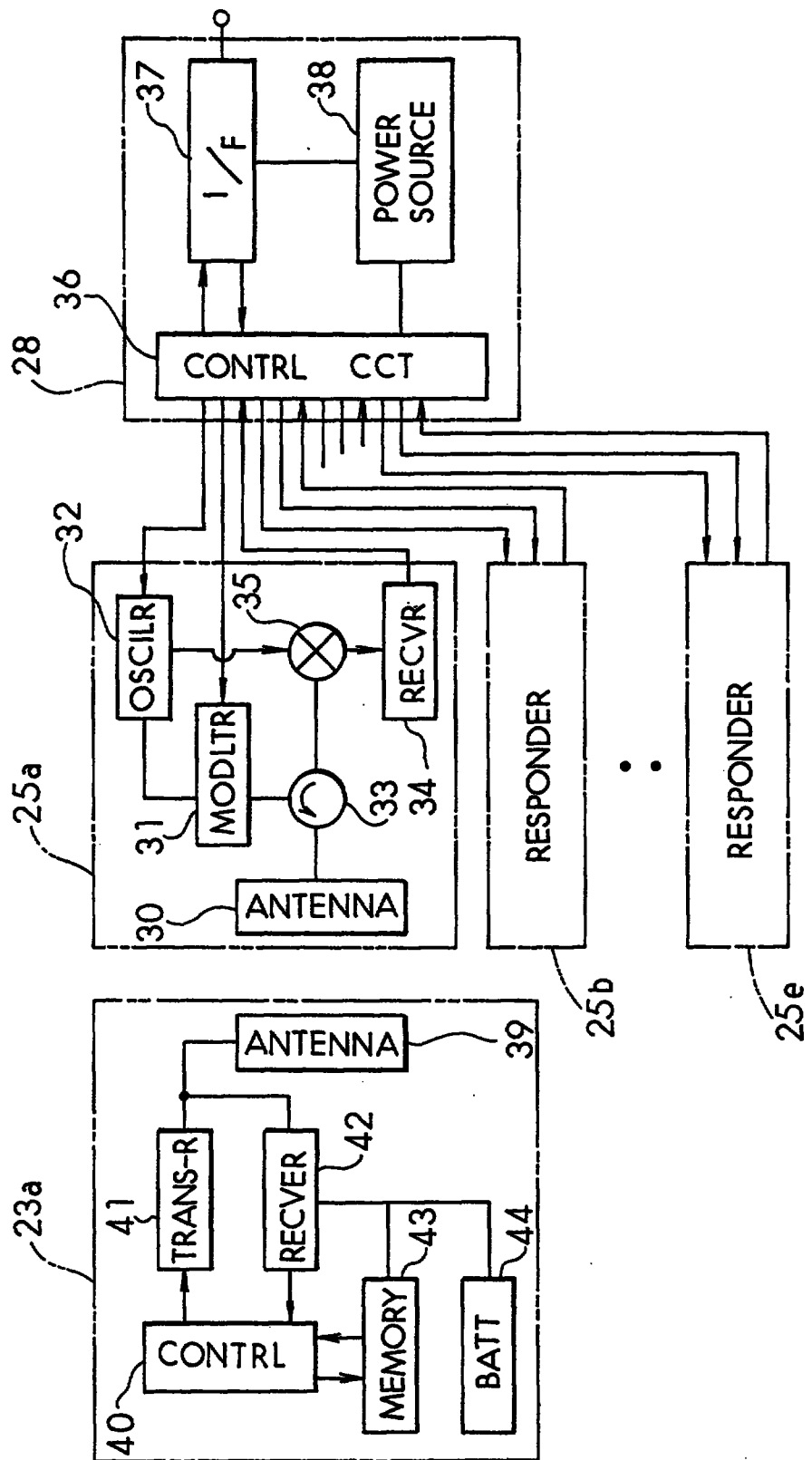


FIG. 2

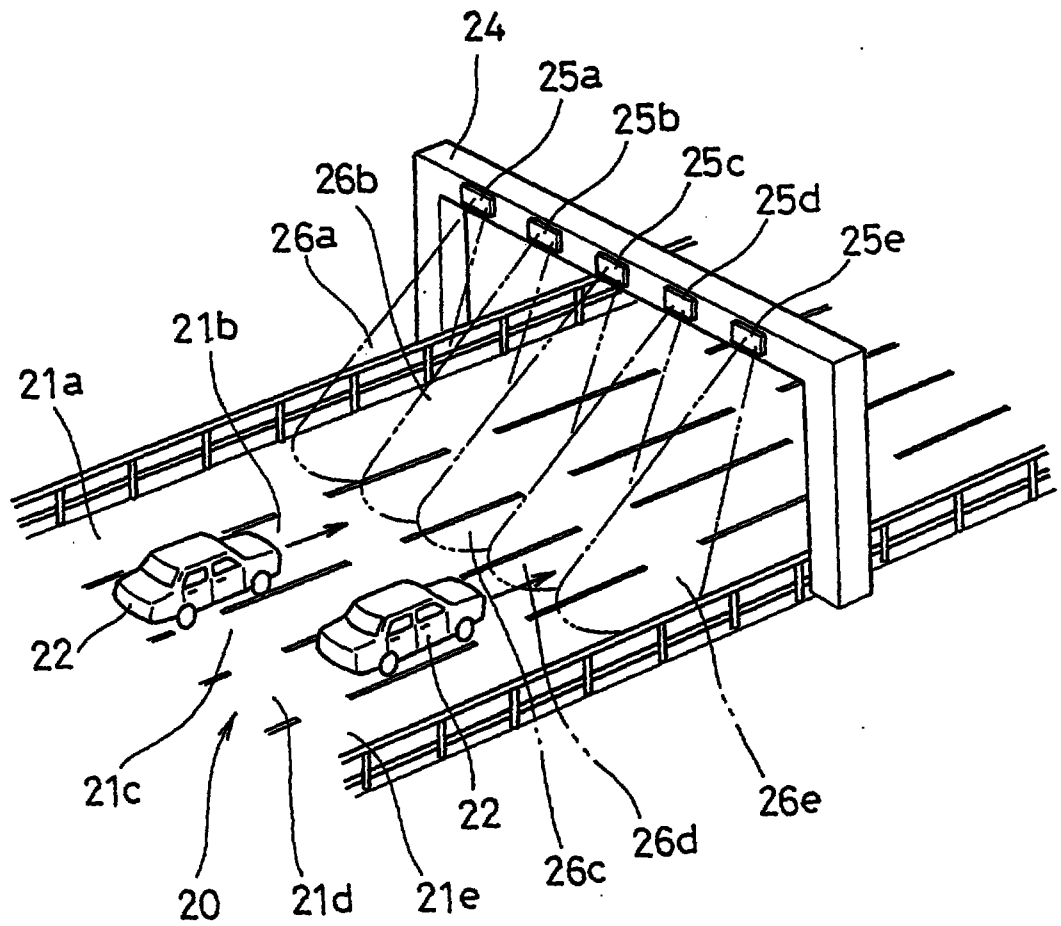


FIG. 3

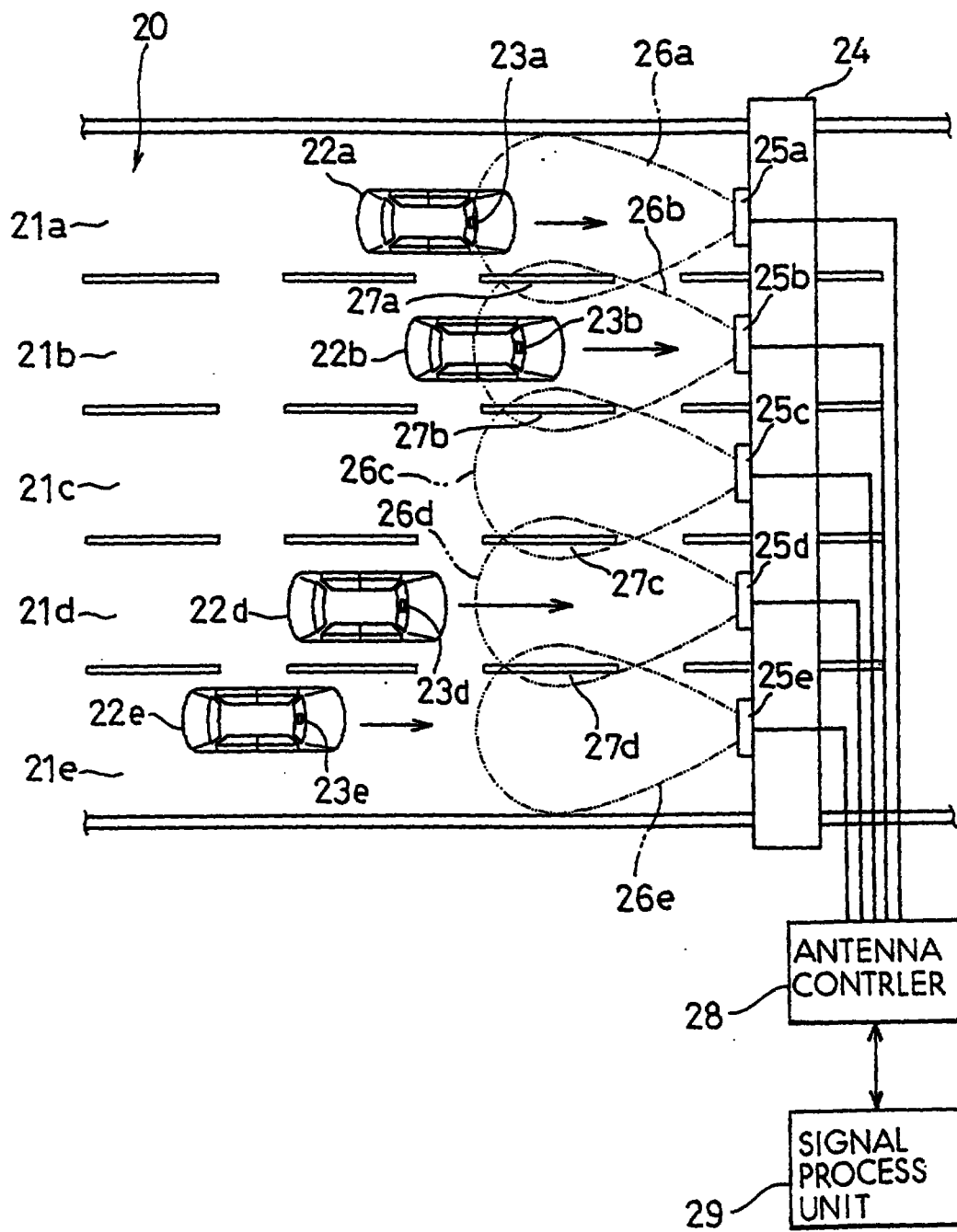


FIG. 4

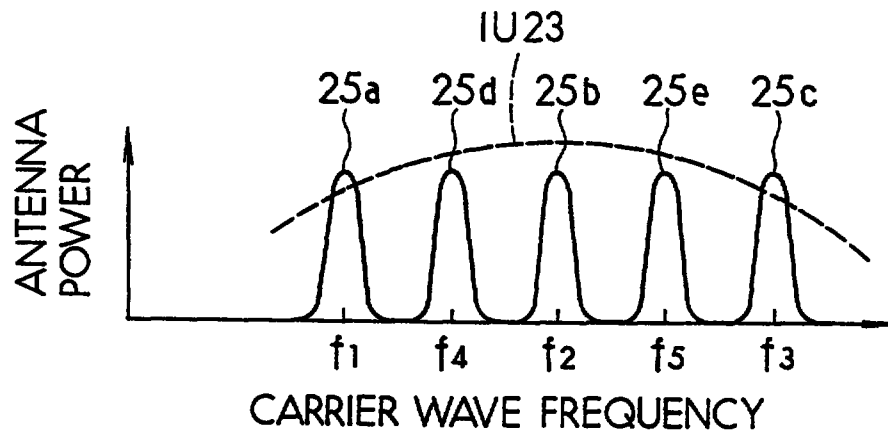


FIG. 5A

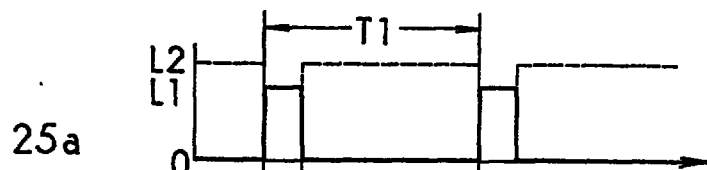


FIG. 5B

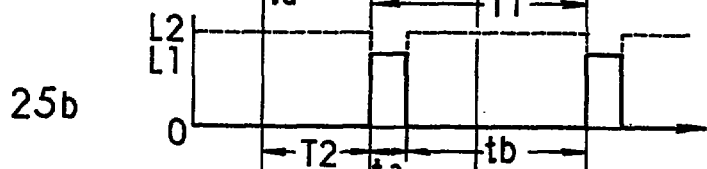


FIG. 5C

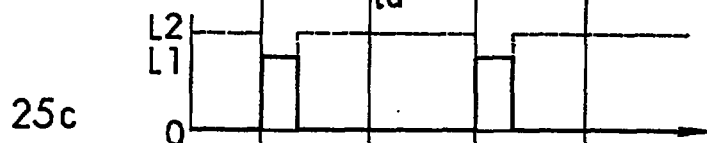


FIG. 5D

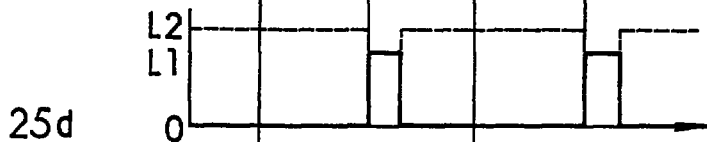


FIG. 5E

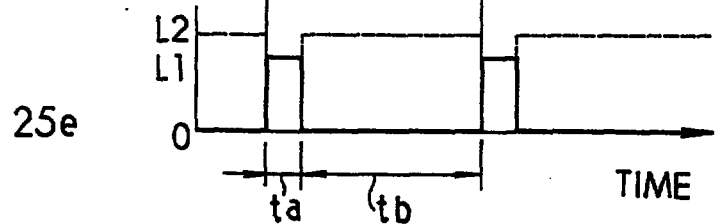


FIG. 6

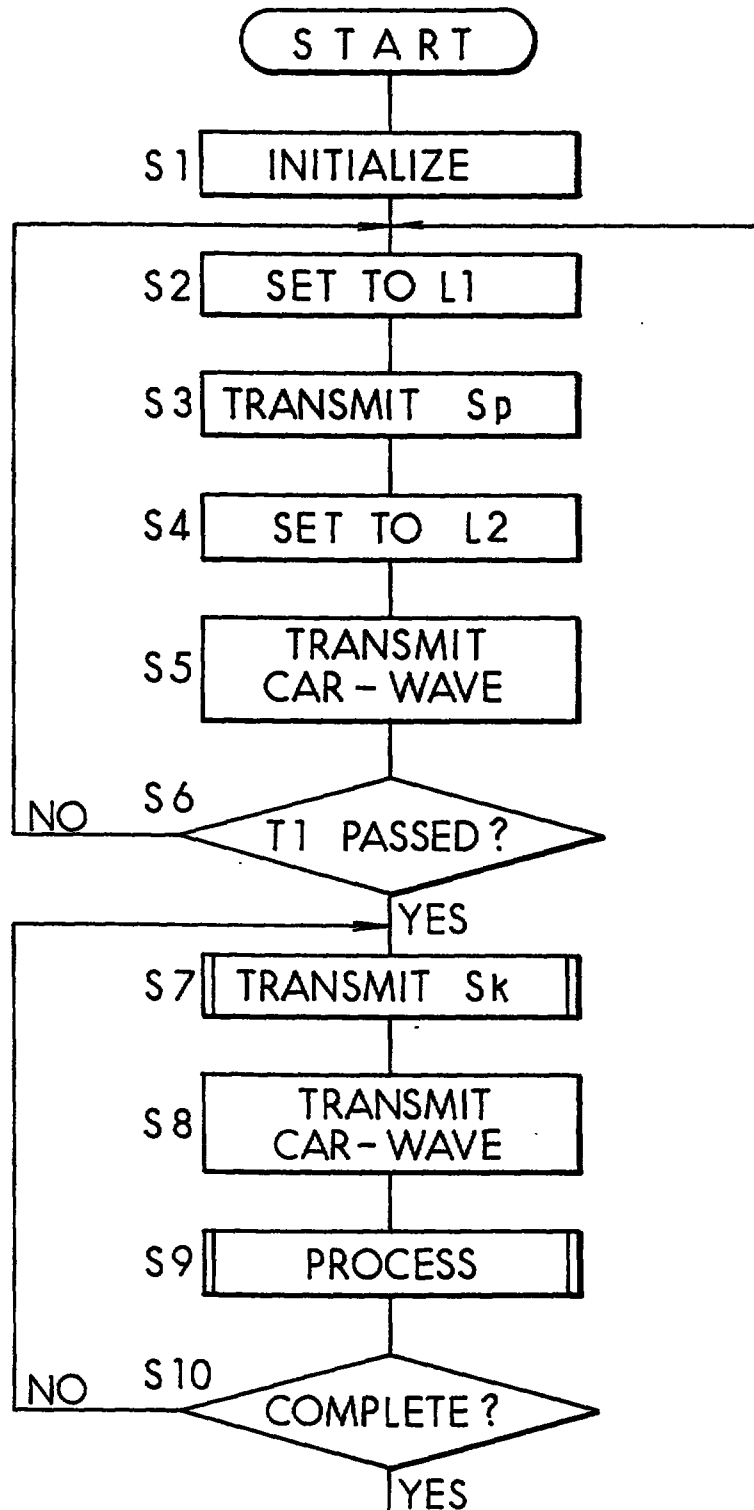


FIG. 7

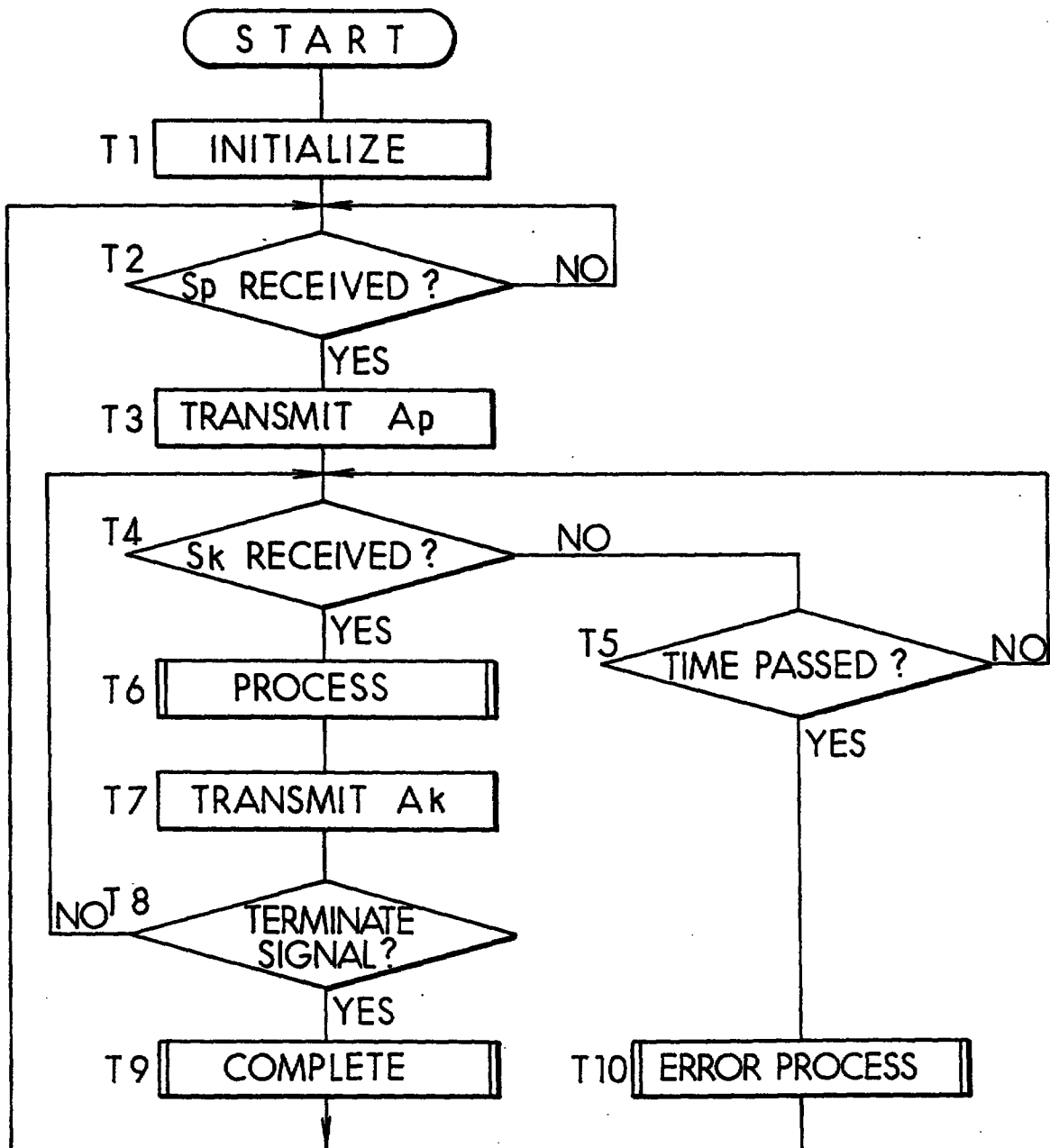


FIG. 8A

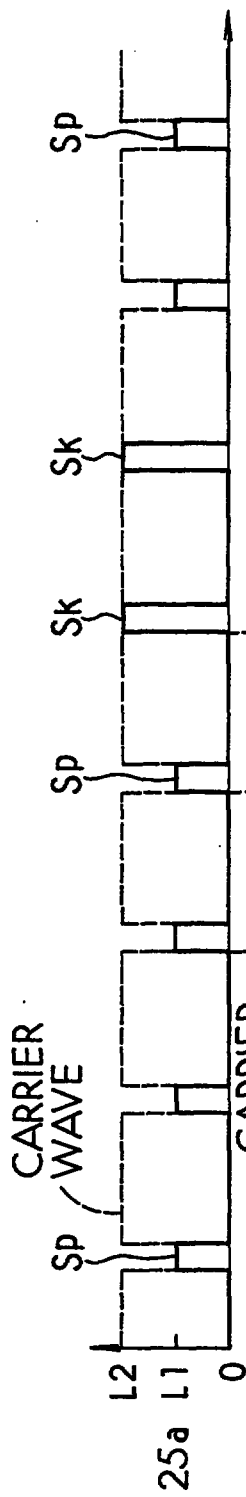


FIG. 8B

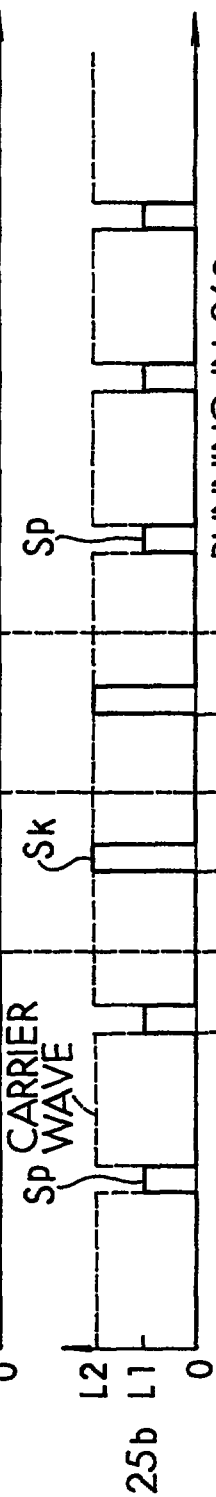


FIG. 8C

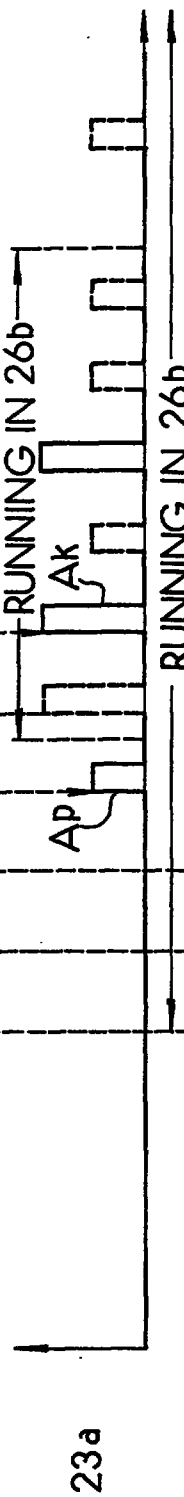


FIG. 8D

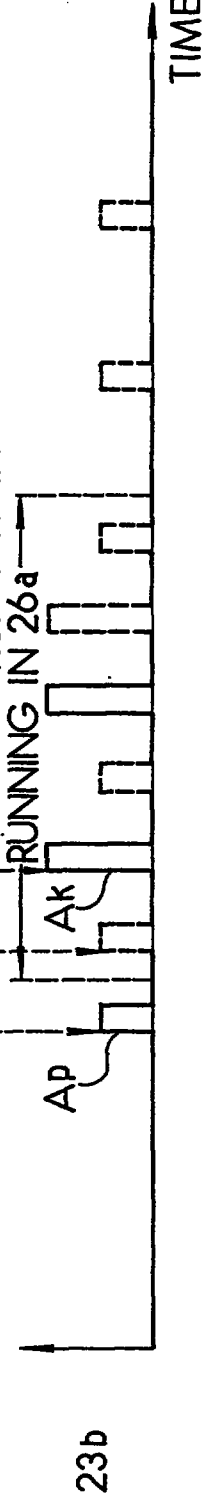
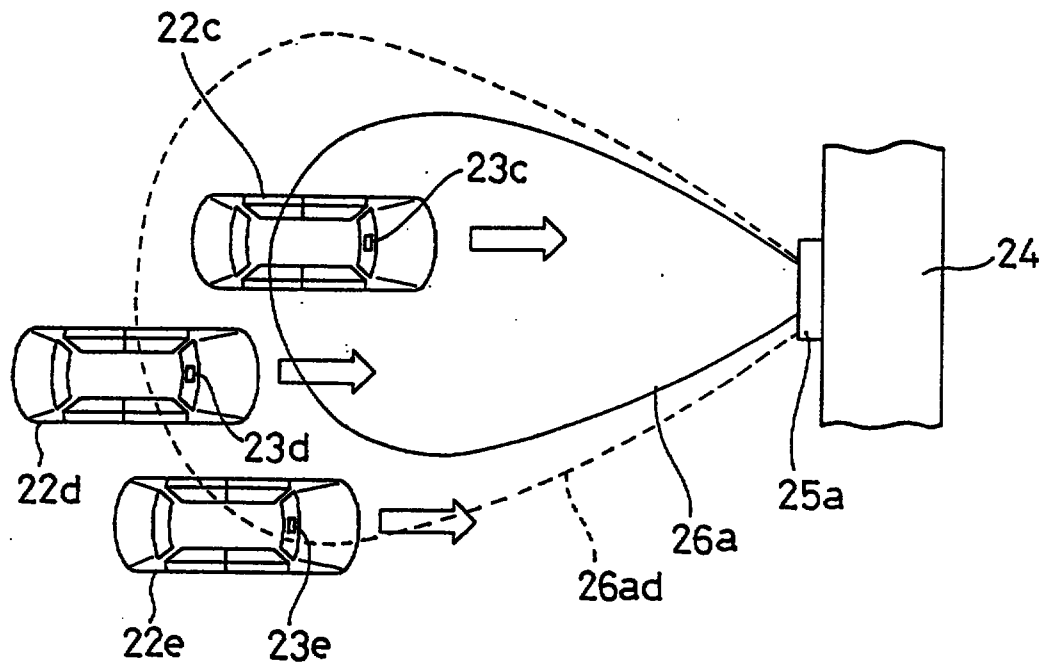
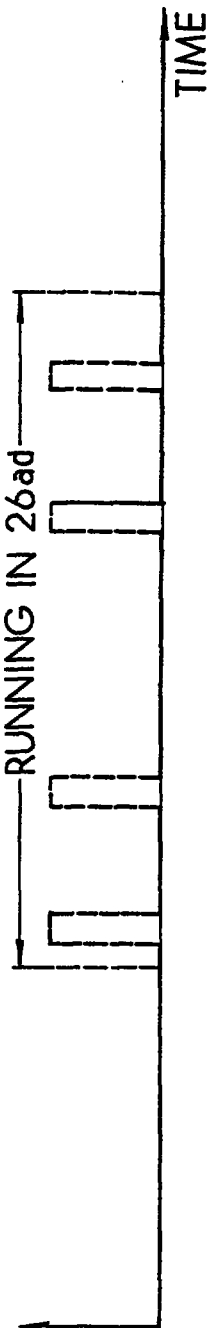
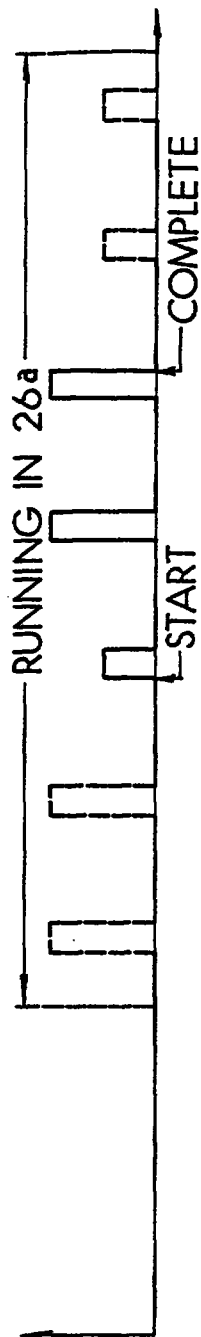
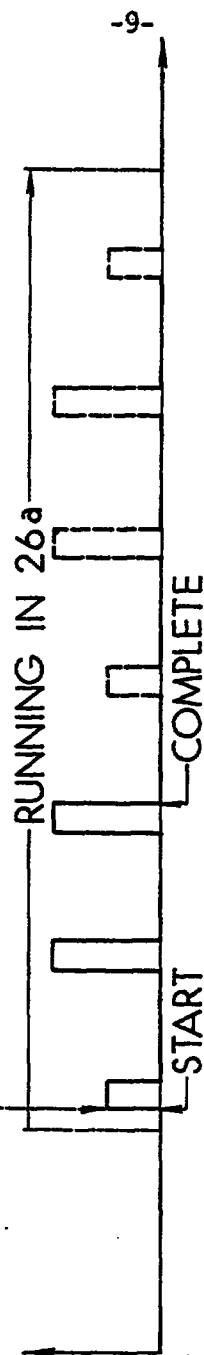
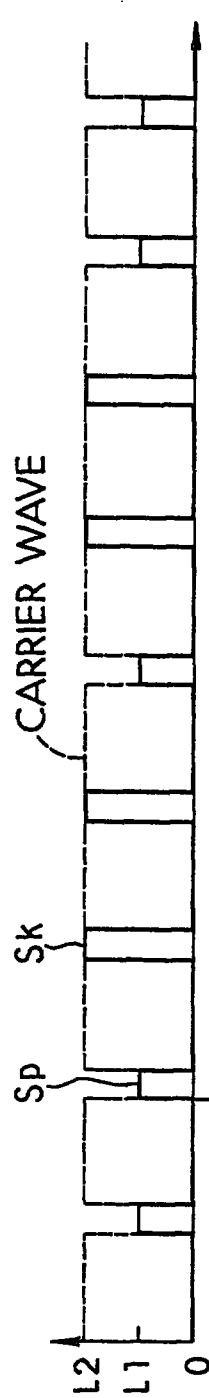


FIG. 9





TIME

FIG. 11 PRIOR ART

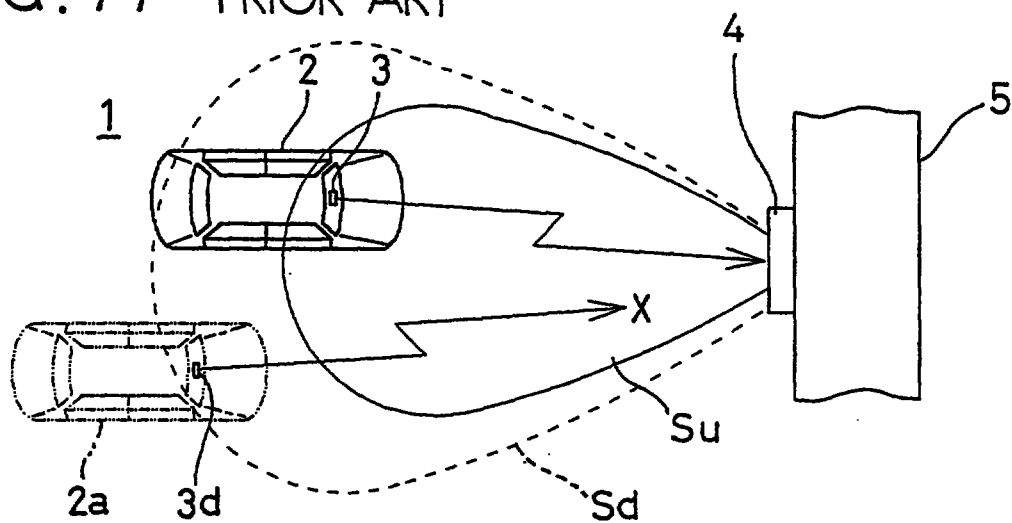
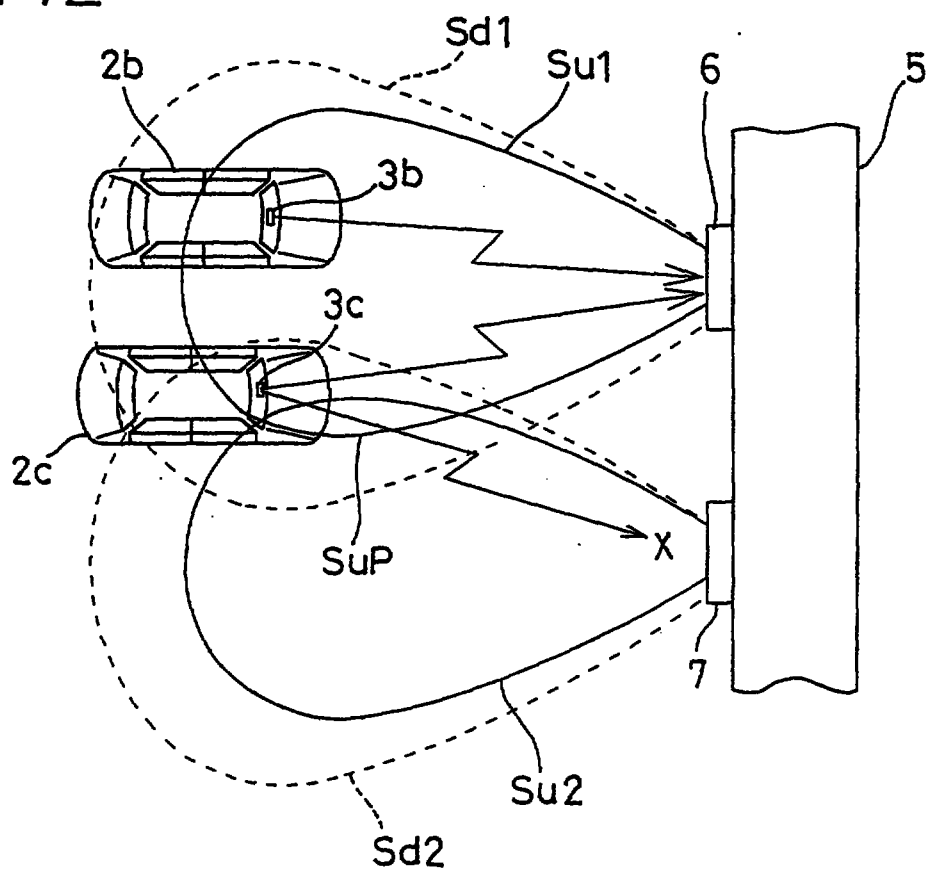


FIG. 12



ABSTRACT

MOBILE OBJECT IDENTIFICATION DEVICE

A communication area for an antenna disposed on a toll collection gate and a communication area for a responder unit (IU) mounted on an automobile are arranged to coincide with each other, and communication failure in intervening areas when a plurality of communication areas are formed in a toll collection area. When an IU mounted on an automobile receives a pilot signal-wave, it modulates a carrier-radio-wave-signal which is subsequently transmitted thereto with a responding data-signal and transmits the modulated-carrier-radio-wave as a responding signal-wave. In this system, the output power of the responding signal-wave is attenuated during the round trip of the carrier-radio-wave. Therefore, the output power thereof is decreased from an original level when the pilot signal-wave is transmitted. On the other hand, when other signal waves are transmitted, their output power are restored to the original level, thereby equalizing the power of the responding signal of the IU and that of the communication signals from the antenna thereby ensuring steady communication.

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THIS SHEET HAS BEEN
REPLACED

ABSTRACT

(Replacement Sheet)

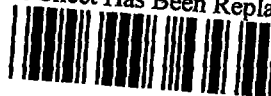
7 March 1996

MOBILE OBJECT IDENTIFICATION DEVICE

A communication area for an antenna disposed on a toll collection gate and a communication area for a responder unit (IU) mounted on an automobile are arranged to coincide with each other, and communication failure in intervening areas when a plurality of communication areas are formed in a toll collection area. When an IU mounted on an automobile receives a pilot signal-wave, it modulates a carrier-radio-wave-signal which is subsequently transmitted thereto with a responding data-signal and transmits the modulated-carrier-radio-wave as a responding signal-wave. In this system, the output power of the responding signal-wave is attenuated during the round trip of the carrier-radio-wave. Therefore, the output power thereof is decreased from an original level when the pilot signal-wave is transmitted. On the other hand, when other signal waves are transmitted, their output power are restored to the original level, thereby equalizing the power of the responding signal of the IU and that of the communication signals from the antenna thereby ensuring steady communication.

(Figure 1)

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

Date : 08 MAR 1996

ABSTRACT

MOBILE OBJECT IDENTIFICATION DEVICE

A communication area for an antenna (30) disposed on a toll collection gate and a communication area for a responder unit (IU) (23a) mounted on an automobile are arranged to coincide with each other, and to prevent communication failure in intervening areas when a plurality of communication areas are formed in a toll collection area. When an IU (23a) mounted on an automobile receives a pilot signal-wave, it modulates a carrier-radio-wave-signal which is subsequently transmitted thereto with a responding data-signal and transmits the modulated-carrier-radio-wave as a responding signal-wave. In this system, the output power of the responding signal wave is attenuated during the round trip of the carrier-radio-wave. Therefore, the output power thereof is decreased from an original level when the pilot signal-wave is transmitted. On the other hand, when other signal waves are transmitted, their output power are restored to the original level, thereby equalizing the power of the responding signal of the IU (23a) and that of the communication signals from the antenna (30) thereby ensuring steady communication.

Figure 1

REPLACEMENT SHEET

14

Date: 04 AUG 1996