

PASSIVE IN-VEHICLE UNIT

[Technical Field]

[0001]

This invention relates to a passive in-vehicle unit designed to increase the power of an RF wave radiated from the in-vehicle unit without increasing the radiated power from a roadside unit.

[Background Art]

[0002]

Among non-stop toll collection systems are an electronic toll collection (ETC) system and an electronic road pricing (ERP) system.

With such non-stop toll collection systems, a wireless communication is conducted between a roadside unit installed on the ground side and an in-vehicle unit installed in a vehicle, whereby toll charging or pricing is performed, so that the vehicle can run without stopping and any cash.

[0003]

In-vehicle units include an active in-vehicle unit with an oscillator for RF wave, and a passive in-vehicle unit without an oscillator for RF wave.

The passive in-vehicle unit reflects and modulates an RF wave transmitted from the roadside unit (downlink RF wave), and transmits (returns) the thus reflected and modulated RF wave to the roadside unit as an uplink RF wave.

[0004]

An explanation will now be offered for the ERP system adopting a passive in-vehicle unit.

The ERP system is a system for charging a toll

(so-called pricing) to a vehicle entering a predetermined restricted zone (for example, the center of the capital city). By this pricing, an attempt is made to suppress the influx of vehicles into the restricted zone (e.g., the center of the capital city), thereby relieving traffic congestion, or to establish a source of financing for transportation infrastructural development.

[0005]

With the ERP system, as shown in Fig. 6, a gantry 2 which is a gate-shaped structure is installed astride a road 1, and this gantry 2 is equipped with an antenna 3 connected to the roadside unit.

A vehicle 4 is equipped with a passive in-vehicle unit 5.

When the vehicle 4 runs below the gantry 2, communication between the antenna 3 and the in-vehicle unit 5 is carried out by an RF wave in the quasi-microwave band (for example, 2360 MHz), and the charging is automatically performed, with the vehicle 4 in a non-stop state.

[0006]

The state of communication between the antenna 3 and the in-vehicle unit 5 will be described with reference to Fig. 7 which is a time chart.

A modulated wave MW and a carrier wave (nonmodulation wave) CW succeeding the modulated wave MW are transmitted from the antenna 3 as a wave corresponding to one slot of communication. The modulated wave MW contains, as information, such information as one showing an entrance to the ERP system.

The in-vehicle unit 5 receives the modulated wave MW and demodulates it to determine that the vehicle 4 has

arrived at the entrance to the ERP system. Then, the in-vehicle unit 5 reflects and modulates the carrier wave CW succeeding the modulated wave MW to transmit it as an in-vehicle unit output RF wave UW. The in-vehicle unit output RF wave UW contains, as information, ID information of the in-vehicle unit 5, for example.

The antenna 3 receives the in-vehicle unit output RF wave UW to calculate a charged toll and perform pricing via a subsequent communication.

[Summary of Invention]

[Technical Problem]

[0007]

The above-described passive in-vehicle unit 5 has no oscillator circuit, and is thus advantageous in that it is simple in apparatus configuration and is inexpensive.

This passive in-vehicle unit 5, however, electrically reflects the carrier wave CW, which has been transmitted from the antenna 3, as such and returns it to the antenna 3 as the in-vehicle unit output RF wave UW. Thus, the power of the in-vehicle unit output RF wave UW is weak.

For this reason, if an RF wave from other radio system (for example, wide area wireless LAN), which has a frequency close to the frequency of the RF wave used in the ERP system, enters the communication zone of the ERP system, interference between the RF waves may occur, making reliable pricing impossible.

[0008]

An increase of the radiated power from the antenna 3 is expected to boost the in-vehicle unit output RF wave UW accordingly, and successfully prevent a trouble due to electromagnetic interference. Actually, however, the

power of the RF wave radiated from the antenna 3 cannot be increased.

[0009]

The reasons are as follows:

There may be a case where a violation vehicle passes which cannot be subjected to appropriate pricing, for example, because of the insertion of a wrong card into the in-vehicle unit, or an insufficient balance in the card. Hence, it is very important for the system to identify the violation vehicle from the viewpoint of fair charge. In order to realize the proper identification of the vehicles, it is mandatory to match the detection result with the communication result. The detection result can be obtained from the sensors installed around the far edge of the communication zone, not shown in the figure.

Therefore, when the power of the RF wave radiated from the antenna of the roadside unit is increased, the communication zone is in excess of detection point. This causes the mistake of identification. Furthermore, the system has already been put to widespread use, so it is difficult to change the detection point by moving the installed sensors. Thus, the power of the RF wave from the antenna 3 cannot be increased.

[0010]

The present invention has been accomplished in the light of the above-mentioned earlier technologies. It is an object of this invention to provide a passive in-vehicle unit which can increase the power of the in-vehicle unit output RF wave retransmitted from the in-vehicle unit to the antenna connected to the roadside unit without modifying the roadside unit and its antenna.

[Solution to Problem]

[0011]

A first aspect of the present invention for solving the above problems is a passive in-vehicle unit, including an antenna for receiving an RF wave transmitted from an antenna connected to a roadside unit, and

an in-vehicle unit circuit for reflecting and modulating the RF wave received by the antenna to create a return RF wave, and outputting the return RF wave so as to be transmitted from the antenna,

the passive in-vehicle unit comprising

a semiactive circuit for allowing the RF wave received by the antenna to pass unchanged, transferring the RF wave to the in-vehicle unit circuit, amplifying the return RF wave outputted from the in-vehicle unit circuit, and then transferring the amplified return RF wave to the antenna.

[0012]

According to a second aspect of the present invention, the in-vehicle unit circuit may comprise a control module for outputting a wake-up signal upon inputting of the RF wave received by the antenna, and a regulator for supplying electric power to the semiactive circuit when the wake-up signal is outputted.

[0013]

According to a third aspect of the present invention, the semiactive circuit may include a first coupler and a second coupler, each having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port and the

first port, and outputting the RF wave, which has been inputted to the third port, from the first port, and an amplifier for amplifying the RF wave, the first coupler may be interposed in a transmission line connecting the antenna and the in-vehicle unit circuit, the first port of the first coupler may be disposed on a side of the antenna, and the second port of the first coupler may be disposed on a side of the in-vehicle unit circuit, the second coupler may be interposed in the transmission line nearer the in-vehicle unit circuit than a position of interposition of the first coupler, the first port of the second coupler may be disposed on the side of the antenna, and the second port of the second coupler may be disposed on the side of the in-vehicle unit circuit, and the amplifier may have an input terminal connected to the third port of the second coupler, and may have an output terminal connected to the third port of the first coupler.

[0014]

According to a fourth aspect of the present invention, the first and second couplers may each be composed of a loaded ring directional coupler, the loaded ring directional coupler comprising a coupler in a form of a rectangular frame and formed from a distributed element (for example, a coupler, a ring directional coupler, or a loaded ring directional coupler), many periodic stubs loaded on each side of the coupler and each formed from a distributed element, four port terminals formed at four corners of the coupler and each formed from a distributed element, and a terminator for terminating one of the port terminals.

[0015]

According to a fifth aspect of the present invention,

circulators, each having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port, and outputting the RF wave, which has been inputted to the third port, from the first port, may be used as the couplers.

[0016]

A sixth aspect of the present invention for solving the above problems is a passive in-vehicle unit, comprising:

- a receiving antenna for receiving an RF wave transmitted from an antenna connected to a roadside unit;

- an in-vehicle unit circuit for reflecting and modulating the RF wave received by the receiving antenna to create a return RF wave, and outputting the return RF wave;

- a semiactive circuit for allowing the RF wave received by the receiving antenna to pass unchanged, transferring the RF wave to the in-vehicle unit circuit, amplifying the return RF wave outputted from the in-vehicle unit circuit, and then outputting the amplified return RF wave; and

- a transmitting antenna for transmitting the amplified return RF wave outputted from the semiactive circuit, and

wherein the semiactive circuit includes

- a coupler having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port and the first port,

and outputting the RF wave, which has been inputted to the third port, from the first port, and

an amplifier for amplifying the RF wave,

the coupler is interposed in a transmission line connecting the receiving antenna and the in-vehicle unit circuit, the first port of the coupler is disposed on a side of the receiving antenna, and the second port of the coupler is disposed on a side of the in-vehicle unit circuit, and

the amplifier has an input terminal connected to the third port of the coupler, and has an output terminal connected to the transmitting antenna.

[0017]

According to a seventh aspect of the present invention, in the sixth aspect of the invention, the in-vehicle unit circuit may comprise a control module for outputting a wake-up signal upon inputting of the RF wave received by the antenna, and a regulator for supplying electric power to the semiactive circuit when the wake-up signal is outputted.

[0018]

According to an eighth aspect of the present invention, in the sixth aspect of the invention, the coupler may be composed of a loaded ring directional coupler, the loaded ring directional coupler comprising a coupler in a form of a rectangular frame and formed from a distributed element, many periodic stubs loaded on each side of the coupler and each formed from a distributed element, four port terminals formed at four corners of the coupler and each formed from a distributed element, and a terminator for terminating one of the port terminals.

[0019]

According to a ninth aspect of the present invention, in the sixth aspect of the invention, a circulator, having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port, and outputting the RF wave, which has been inputted to the third port, from the first port, may be used as the coupler.

[Advantageous Effects of Invention]

[0020]

With the present invention, the semiactive circuit, which allows the downlink RF wave received by the antenna to pass as such, transfers it to the in-vehicle unit circuit, amplifies the uplink RF wave outputted from the in-vehicle unit circuit, and then transfers it to the antenna, is provided between the antenna and the in-vehicle unit circuit. Thus, the power of the uplink RF wave returned from the in-vehicle unit to the antenna can be increased, without changes in the working conditions of the roadside unit and its antenna. As a result, the uplink RF wave becomes free from interference by an RF wave of other radio system, and reliable pricing can be performed.

[0021]

Moreover, the loaded ring directional coupler composed of a distributed element (for example, a microstrip line), small in size, and tolerant of heat is used as the coupler for use in the semiactive circuit. Thus, the semiactive circuit, accordingly, the in-vehicle unit, can be downsized, and a thermally strong in-vehicle unit can be achieved.

[Brief Description of Drawings]

[0022]

Fig. 1 is a block configurational drawing showing a passive in-vehicle unit according to Embodiment 1 of the present invention.

Fig. 2 is a block configurational drawing showing a passive in-vehicle unit according to Embodiment 2 of the present invention.

Fig. 3 is a block configurational drawing showing a semiactive circuit used in Embodiments 1 and 2 of the present invention.

Fig. 4 is a circuit configurational drawing showing a loaded directional coupler used as a coupler of the semiactive circuit.

Fig. 5 is a block configurational drawing showing a passive in-vehicle unit according to Embodiment 4 of the present invention.

Fig. 6 is a schematic view showing an ERP system.

Fig. 7 is an explanation drawing showing a communication method in the ERP system.

[Description of Embodiments]

[0023]

The best mode for putting the present invention into practice will now be described in detail based on embodiments of the invention.

[Embodiment 1]

[0024]

Fig. 1 shows a passive in-vehicle unit 100 according to Embodiment 1 of the present invention. The in-vehicle unit 100 has a transmitting/receiving antenna 101, an in-vehicle unit circuit 110, and a semiactive circuit 120.

The transmitting/receiving antenna 101, the

in-vehicle unit circuit 110, and the semiactive circuit 120 are electromagnetically connected together by a transmission line L.

[0025]

In the in-vehicle unit 100, the transmitting/receiving antenna 101 and the in-vehicle unit circuit 110 are components (constituent circuits) provided in a conventional in-vehicle unit. The in-vehicle unit 100 of Embodiment 1 is characterized in that the semiactive circuit 120 is newly provided between the transmitting/receiving antenna 101 and the in-vehicle unit circuit 110.

[0026]

The transmitting/receiving antenna 101 receives a modulated wave MW and a carrier wave CW transmitted from an antenna 3, which is connected to a roadside unit, and transmits an in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110 toward the antenna 3 connected to the roadside unit.

[0027]

The semiactive circuit 120 (its detailed configuration will be described later) allows the modulated wave MW and the carrier wave CW received by the transmitting/receiving antenna 101 to pass unchanged, and transfers them to the in-vehicle unit circuit 110. The semiactive circuit 120 also amplifies the in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110, and transfers it to the transmitting/receiving antenna 101.

That is, the semiactive circuit 120 has the properties of passing the downlink RF wave as such for transfer, and amplifying the uplink RF wave for transfer.

A concrete configurational example of the semiactive circuit 120 will be described later in Embodiment 3.

[0028]

The in-vehicle unit circuit 110 has a switching circuit 111, a detector 112, an amplifier 113, a modulator consisting of the switching circuit 111 and a reflection line 114, and a control unit (CPU) 115.

[0029]

The reflection line 114 is constituted by forming a copper-foil transmission line on a substrate. The transmission line is of a rectangular shape, and its length in the transfer or transmission direction of an RF wave is $\lambda/4$, provided that the wavelength of the carrier wave CW is λ . Thus, when the carrier wave CW is incident on the reflection line 114 through the switching circuit 111, and is then reflected, the phase of the reflected carrier wave CW is shifted $\lambda/2$ with respect to the phase of the incident wave (i.e., the phase is inverted).

[0030]

When the modulated wave MW or the carrier wave CW transmitted from the antenna 3 of the roadside unit is received by the transmitting/receiving antenna 101, the modulated wave MW and the carrier wave CW that have been received are passed through the semiactive circuit 120 and transferred to the in-vehicle unit circuit 110.

[0031]

Upon reception of the modulated wave MW into the in-vehicle unit circuit 110, the modulated wave MW is inputted to the detector 112 via the switching circuit 111. The detector 112 detects the modulated wave MW to demodulate received data a, and the received data a is

amplified by the amplifier 113 and then inputted into the control unit 115.

[0032]

The control unit 115 receives the received data a to determine, for example, that the vehicle has arrived at the entrance to the ERP system, whereafter the control unit 115 outputs transmitted data b which is a digital signal. The transmitted data b includes, for example, ID information on the in-vehicle unit 100.

[0033]

The transmitted data b is sent to the switching circuit 111, and the switching circuit 111 performs a switching action in response to the high state (H) or the low state (L) of the transmitted data b.

When the switching circuit 111 is open (in OFF-state), the carrier wave CW is reflected by the switching circuit 111.

When the switching circuit 111 is thrown (in ON-state), the carrier wave CW is reflected by the reflection line 114. The phase difference of the reflected RF wave is 180 degrees when the switching circuit is open or thrown because the length of the reflection line is set to be $\lambda/4$.

[0034]

In the above-described manner, the switching circuit 111 is allowed to perform a switching action in response to the transmitted data b. Thus, the position of reflection of the carrier wave CW differs, with the result that the phase of the reflected RF wave changes, and binary phase-shift keying (BPSK) takes place. A reflected RF wave created upon this binary phase-shift keying of the carrier wave CW becomes the in-vehicle unit

output RF wave UW, which is outputted from the in-vehicle unit circuit 110.

[0035]

The in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110 is amplified by the semiactive circuit 120, and then transferred to the transmitting/receiving antenna 101. Then, the wave UW is transmitted (returned) from the transmitting/receiving antenna 101.

The power of the in-vehicle unit output RF wave UW has been increased by the semiactive circuit 120. Thus, even if an RF wave from other radio system (for example, wide area wireless LAN) slips in, the in-vehicle unit output RF wave UW is markedly relieved from interference with the slipping-in RF wave, but is surely received by the antenna 3 of the roadside unit. Hence, reliable pricing can be performed.

[0036]

With the in-vehicle unit 100 of Embodiment 1, the transmitting/receiving antenna 101 and the in-vehicle unit circuit 110 are components (constituent circuits) used in the conventional in-vehicle unit, so that conventional design technologies can be applied, unchanged, for the transmitting/receiving antenna 101 and the in-vehicle unit circuit 110 which are the same constituent parts as before. Thus, reliable experiences with and know-how about design and manufacturing accumulated by the conventional technologies can be utilized as such. As a result, the in-vehicle unit 100 of Embodiment 1 becomes a reliable product.

[0037]

No specification changes are made for the roadside

unit such as the antenna 3. Thus, the conventional in-vehicle unit already in operation can be used unchanged together with the new semiactive in-vehicle unit.

Furthermore, the power of the RF wave radiated from the antenna 3 is not increased. Thus, the system can secure the same communication zone, which enables the system to achieve the good identification of passing vehicles as before.

[Embodiment 2]

[0038]

A passive in-vehicle unit 100a according to Embodiment 2 of the present invention will be described with reference to Fig. 2.

[0039]

The in-vehicle unit 100a of Embodiment 2 has a wake-up function added to the in-vehicle unit 100 of Embodiment 1.

[0040]

A regulator 116 is provided in an in-vehicle unit circuit 110a of the in-vehicle unit 100a. The regulator 116 has the functions of supplying electric power of regulated voltage to the amplifier 113 and other power consuming elements within the in-vehicle unit circuit 110a, and also supplying it to the semiactive circuit 120.

[0041]

The control unit 115 has the function of outputting a wake-up signal c to the regulator 116, when the modulated wave MW is received by the in-vehicle unit circuit 110a, and the received data a is inputted from the detector 112. The control unit 115 continues to output the wake-up signal c throughout the period during which the RF waves MW and CW received by the transmitting/receiving antenna 101 are

inputted into the in-vehicle unit circuit 110a.

[0042]

The regulator 116 stops the supply of electric power when not receiving the wake-up signal c from the control unit 115, but supplies electric power at regulated voltage to the receiver block of the circuit 110a such as the amplifier 113.

[0043]

Thus, only during the period of communication upon transmission and reception of the RF wave between the in-vehicle unit 100a and the antenna 3 of the roadside unit, power supply to the semiactive circuit 120 is performed. For other periods of time, no power supply is carried out to the semiactive circuit 120. Although the semiactive circuit 120 is provided, therefore, wasteful power consumption does not take place, power consumption can be decreased, and overdischarge of the power source (battery of the vehicle) can be prevented.

[0044]

The other portions are configured in the same manner as in Embodiment 1. Thus, the portions performing the same functions are assigned the same numerals and symbols as in Embodiment 1, and duplicate explanations are omitted.

[Embodiment 3]

[0045]

Next, the concrete configuration of the semiactive circuit 120 used in each of the in-vehicle units 100 and 100a according to Embodiment 1 and Embodiment 2 will be described with reference to Fig. 3.

As shown in Fig. 3, the semiactive circuit 120 is disposed in a state interposed in the transmission line L connecting the transmitting/receiving antenna 101 and

the in-vehicle unit circuit 110 (or 110a).

[0046]

The semiactive circuit 120 is composed of two 3-port couplers, 121 and 122, and an amplifier 123.

As the couplers 121, 122, there can be used general-purpose couplers produced from a magnetized ferrite material, or loaded ring directional couplers formed from a distributed element such as a microstrip line to be described later.

[0047]

The first coupler 121 has a first port #11, a second port #12, and a third port #13. The first coupler 121 has the properties of outputting the RF wave, which has been inputted to the first port #11, from the second port #12, outputting the RF wave, which has been inputted to the second port #12, from the third port #13 and the first port #11, and outputting the RF wave, which has been inputted to the third port #13, from the first port #11.

[0048]

Likewise, the second coupler 122 has a first port #21, a second port #22, and a third port #23. The second coupler 122 has the properties of outputting the RF wave, which has been inputted to the first port #21, from the second port #22, outputting the RF wave, which has been inputted to the second port #22, from the third port #23 and the first port #21, and outputting the RF wave, which has been inputted to the third port #23, from the first port #21.

[0049]

The first coupler 121 is interposed in the transmission line L, and has the first port #11 disposed on the side of the transmitting/receiving antenna 101 and

the second port #12 disposed on the side of the in-vehicle unit circuit 110 (110a).

The second coupler 122 is interposed in the transmission line L toward the in-vehicle unit circuit 110 (110a) with respect to the position of interposition of the first coupler 121, and has the first port #21 disposed on the side of the transmitting/receiving antenna 101 and the second port #22 disposed on the side of the in-vehicle unit circuit 110 (110a).

[0050]

The amplifier 123 having the function of amplifying the RF wave has an input terminal connected to the third port #23 of the second coupler 122 and an output terminal connected to the third port #13 of the first coupler 121.

[0051]

With the semiactive circuit 120 of the foregoing configuration, the modulated wave MW and the carrier wave CW received by the transmitting/receiving antenna 101 are transferred along the following path: the first port #11 of the first coupler 121 → the second port #12 of the first coupler 121 → the first port #21 of the second coupler 122 → the second port #22 of the second coupler 122. That is, the modulated wave MW and the carrier wave CW received by the transmitting/receiving antenna 101 are passed through the semiactive circuit 120, and transferred or transmitted to the in-vehicle unit circuit 110 (110a). On this occasion, the couplers 121 and 122 undergo little transmission loss.

[0052]

The in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110 (110a) is transferred or transmitted toward the transmitting/receiving antenna

101 via the following route: the second port #22 of the second coupler 122 → the third port #23 of the second coupler 122 → the amplifier 123 → the third port #13 of the first coupler 121 → the first port #11 of the first coupler 121.

On this occasion, the in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110 (110a) is amplified by the amplifier 123. Thus, the amplified in-vehicle unit output RF wave UW of increased RF wave power is transmitted from the transmitting/receiving antenna 101.

[0053]

Next, a loaded ring directional coupler 200 formed from a distributed element such as a microstrip line, which can be used as the coupler 121 or 122, will be described with reference to Fig. 4.

[0054]

The loaded ring directional coupler 200 shown in Fig. 4 is used as the coupler 121 or 122 shown in Fig. 3.

[0055]

The loaded ring directional coupler 200 is constituted by forming a copper-foil and a substrate which works as the distributed element such as the microstrip line at high frequency.

As a further explanation, the loaded ring directional coupler 200 is composed of a ring directional coupler 201 in the form of a rectangular frame, many periodic stubs 202 loaded on each side of the ring directional coupler 201, four port terminals 203a, 203b, 203c and 203d formed at the four corners of the ring directional coupler 201, and a terminator 204 for terminating the port terminal

203d.

[0056]

Since the ring directional coupler 201 has the many periodic stubs 202 loaded on each side thereof, the length of one side thereof is less than $\lambda/4$, provided that the wavelength of the RF wave MW, CW or UW is λ . Thus, the ring directional coupler 201 can be downsized.

The ends of the four port terminals 203a, 203b, 203c and 203d are first to fourth ports #1 to #4.

[0057]

The first port #1, the second port #2 and the third port #3 of the loaded ring directional coupler 200 correspond to the first port #11, the second port #12 and the third port #13 of the first coupler 121, and also correspond to the first port #21, the second port #22 and the third port #23 of the second coupler 122.

That is, the loaded ring directional coupler 200 has the properties of outputting the RF wave, which has been inputted to the first port #1, from the second port #2, outputting the RF wave, which has been inputted to the second port #2, from the third port #3 and the first port #1, and outputting the RF wave, which has been inputted to the third port #3, from the first port #1.

[0058]

The loaded ring directional coupler 200 has the periodic stubs 202 loaded on the ring directional coupler 201, and thus is small in the entire size as compared with a conventional ring directional coupler having no periodic stubs loaded thereon.

Moreover, the loaded ring directional coupler 200 is composed by forming the distributed element such as the copper-foil microstrip line on the substrate, and is

tolerant of heat.

Incidentally, a general-purpose coupler composed of magnetized ferrite has the problem that its magnetic properties tend to be deteriorated by heat.

[0059]

If the loaded ring directional coupler 200 of a small size configured in the above-described manner is adopted as the coupler 121 or 122 of the semiactive circuit 120, the downsizing of the semiactive circuit 120, accordingly, the downsizing of the in-vehicle unit 100 (100a) can be achieved.

Furthermore, the loaded ring directional coupler 200 is resistant to heat, so that the in-vehicle unit 100 (100a) which is thermally strong can be produced.

[0060]

In addition, general-purpose circulators produced from a magnetized ferrite material can be used as the couplers 121, 122.

The circulator has a first port, a second port, and a third port, and has the properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port, and outputting the RF wave, which has been inputted to the third port, from the first port. Thus, the circulators can be used instead of the couplers 121, 122.

[Embodiment 4]

[0061]

Next, a passive in-vehicle unit 100b according to Embodiment 4 of the present invention will be described by reference to Fig. 5.

The in-vehicle unit 100b has a receiving antenna

102, a transmitting antenna 103, an in-vehicle unit circuit 110a, and a semiactive circuit 130.

The configuration and functions of the in-vehicle unit circuit 110a are the same as those of Embodiment 2 shown in Fig. 2. Thus, explanations for the configuration and actions of the in-vehicle unit circuit 110a will be omitted here.

[0062]

The receiving antenna 102 receives a modulated wave MW and a carrier wave CW transmitted from an antenna 3 connected to a roadside unit. The transmitting antenna 103 transmits an in-vehicle unit output RF wave UW, which has been outputted from the in-vehicle unit circuit 110a and amplified by the semiactive circuit 130, toward the antenna 3.

[0063]

The semiactive circuit 130 is composed of a coupler 131 and an amplifier 132.

As the coupler 131, there can be used a loaded ring directional coupler (see Fig. 4) formed from a distributed element such as a microstrip line as mentioned earlier.

[0064]

The coupler 131 has a first port #31, a second port #32, and a third port #33. The coupler 131 has the properties of outputting the RF wave, which has been inputted to the first port #31, from the second port #32, outputting the RF wave, which has been inputted to the second port #32, from the third port #33 and the first port #31, and outputting the RF wave, which has been inputted to the third port #33, from the first port #31.

In the present embodiment, however, the property of outputting the RF wave, which has been inputted to the

third port #33, from the first port #31 is not utilized.

[0065]

The coupler 131 is interposed in a transmission line L, and has the first port #31 disposed on the side of the receiving antenna 102 and the second port #32 disposed on the side of the in-vehicle unit circuit 110a.

[0066]

The amplifier 132 having the function of amplifying the RF wave has an input terminal connected to the third port #33 of the coupler 131 and an output terminal connected to the transmitting antenna 103.

[0067]

With the semiactive circuit 130 of the foregoing configuration, the modulated wave MW and the carrier wave CW received by the receiving antenna 102 are transferred along the following path: the first port #31 of the first coupler 131 → the second port #32 of the first coupler 131. That is, the modulated wave MW and the carrier wave CW received by the receiving antenna 102 are passed through the semiactive circuit 130, and transferred or transmitted to the in-vehicle unit circuit 110a. On this occasion, the coupler 131 undergoes little transmission loss.

[0068]

The in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110a is transferred or transmitted toward the transmitting antenna 103 via the following route: the second port #32 of the coupler 131 → the third port #33 of the coupler 131 → the amplifier 132.

On this occasion, the in-vehicle unit output RF wave UW outputted from the in-vehicle unit circuit 110a is amplified by the amplifier 132. Thus, the amplified

in-vehicle unit output RF wave UW of increased RF wave power is transmitted from the transmitting antenna 103.

[0069]

The embodiment shown in Fig. 5 is equipped with a regulator 116, but may be without the regulator 116.

[0070]

A general-purpose circulator produced from a magnetized ferrite material can be used instead of the coupler 131.

[Industrial Applicability]

[0071]

The present invention can be used not only as a passive in-vehicle unit for use in the ERP system, but can also be used, unchanged, as a passive in-vehicle unit for use in the ETC system.

[Reference Signs List]

[0072]

- 1 Road
- 2 Gantry
- 3 Antenna connected to roadside unit
- 4 Vehicle
- 5 In-vehicle unit
- 100, 100a, 100b In-vehicle unit
- 101 Transmitting/receiving antenna
- 102 Receiving antenna
- 103 Transmitting antenna
- 110, 110a In-vehicle unit circuit
- 111 Switching circuit
- 112 Detector
- 113 Amplifier
- 114 Reflection line
- 115 Control unit

116 Regulator
120 Semiactive circuit
121, 122 Coupler
123 Amplifier
130 Semiactive circuit
131 Coupler
132 Amplifier
200 Loaded ring directional coupler
201 Ring directional coupler
202 Stub
203a to 203d Port terminal
204 Terminator
L Transmission line

[Citation List]

[Patent Literature]

[0073]

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[Claims]

[Claim 1]

A passive in-vehicle unit, including

an antenna for receiving an RF wave transmitted from an antenna connected to a roadside unit, and

an in-vehicle unit circuit for reflecting and modulating the RF wave received by the antenna to create a return RF wave, and outputting the return RF wave so as to be transmitted from the antenna,

the passive in-vehicle unit comprising

a semiactive circuit for allowing the RF wave received by the antenna to pass unchanged, transferring the RF wave to the in-vehicle unit circuit, amplifying the return RF wave outputted from the in-vehicle unit circuit, and then transferring the amplified return RF wave to the antenna,

wherein the semiactive circuit includes

a first coupler and a second coupler, each having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port and the first port, and outputting the RF wave, which has been inputted to the third port, from the first port, and

an amplifier for amplifying the RF wave,

the first coupler is interposed in a transmission line connecting the antenna and the in-vehicle unit circuit, the first port of the first coupler is disposed on a side of the antenna, and the second port of the first coupler is disposed on a side of the in-vehicle unit circuit,

the second coupler is interposed in the transmission line nearer the in-vehicle unit circuit than a position of

interposition of the first coupler, the first port of the second coupler is disposed on the side of the antenna, and the second port of the second coupler is disposed on the side of the in-vehicle unit circuit, and

the amplifier has an input terminal connected to the third port of the second coupler, and has an output terminal connected to the third port of the first coupler.

[Claim 2]

The passive in-vehicle unit according to claim 1, wherein

the in-vehicle unit circuit comprises

a control module for outputting a wake-up signal upon inputting of the RF wave received by the antenna, and

a regulator for supplying electric power to the semiactive circuit when the wake-up signal is outputted.

[Claim 3]

The passive in-vehicle unit according to claim 1 or 2, wherein

the first and second couplers are each composed of a loaded ring directional coupler,

the loaded ring directional coupler comprising a coupler in a form of a rectangular frame and formed from a distributed element, many periodic stubs loaded on each side of the coupler and each formed from a distributed element, four port terminals formed at four corners of the coupler and each formed from a distributed element, and a terminator for terminating one of the port terminals.

[Claim 4]

The passive in-vehicle unit according to claim 1 or 2,

wherein

circulators, each having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port, and outputting the RF wave, which has been inputted to the third port, from the first port, are used as the couplers.

[Claim 5]

A passive in-vehicle unit, comprising:

a receiving antenna for receiving an RF wave transmitted from an antenna connected to a roadside unit;

an in-vehicle unit circuit for reflecting and modulating the RF wave received by the receiving antenna to create a return RF wave, and outputting the return RF wave;

a semiactive circuit for allowing the RF wave received by the receiving antenna to pass unchanged, transferring the RF wave to the in-vehicle unit circuit, amplifying the return RF wave outputted from the in-vehicle unit circuit, and then outputting the amplified return RF wave; and

a transmitting antenna for transmitting the amplified return RF wave outputted from the semiactive circuit, and

wherein the semiactive circuit includes

a coupler having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port and the first port, and outputting the RF wave, which has been inputted to the

third port, from the first port, and

an amplifier for amplifying the RF wave,

the coupler is interposed in a transmission line connecting the receiving antenna and the in-vehicle unit circuit, the first port of the coupler is disposed on a side of the receiving antenna, and the second port of the coupler is disposed on a side of the in-vehicle unit circuit, and

the amplifier has an input terminal connected to the third port of the coupler, and has an output terminal connected to the transmitting antenna.

[Claim 6]

The passive in-vehicle unit according to claim 5, wherein

the in-vehicle unit circuit comprises

a control module for outputting a wake-up signal upon inputting of the RF wave received by the antenna, and

a regulator for supplying electric power to the semiactive circuit when the wake-up signal is outputted.

[Claim 7]

The passive in-vehicle unit according to claim 5 or 6, wherein

the coupler is composed of a loaded ring directional coupler,

the loaded ring directional coupler comprising a coupler in a form of a rectangular frame and formed from a distributed element, many periodic stubs loaded on each side of the coupler and each formed from a distributed element, four port terminals formed at four corners of the coupler and each formed from a distributed element, and a terminator for terminating one of the port terminals.

[Claim 8]

The passive in-vehicle unit according to claim 5, wherein

a circulator, having a first port, a second port and a third port, and having properties of outputting the RF wave, which has been inputted to the first port, from the second port, outputting the RF wave, which has been inputted to the second port, from the third port, and outputting the RF wave, which has been inputted to the third port, from the first port, is used as the coupler.