ANTENNA, PHASE CONVERTER AND COMMUNICATION APPARATUS

BACKGROUND OF THE INVENTION

i) Technical Field of the Invention

This invention relates to an antenna comprising an antenna body and a phase converter, for transmitting and receiving a circularly polarized radio wave, a phase converter used for the antenna, and a communication apparatus for transmitting and receiving data to and from the outside using the antenna.

ii) Description of the Related Art

Conventionally, there have been antennas for transmitting and receiving a linearly polarized radio wave (vertically polarized wave and horizontally polarized wave) and a circularly polarized radio wave.

For an example of an antenna for transmitting and receiving a circularly polarized radio wave, Fig. 5D shows an antenna 121 (hereinafter, referred to as a fourth conventional antenna 121 as well) comprising an antenna body 123 formed into a nearly circular flat board. The fourth conventional antenna 121 comprises an external I/O terminal 107 as an interface to an external device. The fourth conventional antenna 121 outputs a signal detected in the antenna body 123 to

the external device via the external I/O terminal 107, and also outputs a radio wave from the antenna body 123 according to a signal inputted from the external device via the external I/O terminal 107. In the central position of the antenna body 123, an earth point 123b is provided which is electrically connected with a ground portion provided on the back face of the board via a through-hole formed piercingly through the board. The external I/O terminal 107 is electrically connected to a feeding point 123a formed on the antenna body 123 via a wire having a length corresponding to an intra-line wavelength λg of the radio wave which is transmitted and received.

The fourth conventional antenna 121 comprising the circularly formed antenna body 123 can transmit and receive a circularly polarized radio wave. However, a frequency bandwidth of the radio wave which can be transmitted and received is narrow.

On the other hand, as shown in Fig. 5C, there is an antenna 111 (hereinafter, referred to as a third conventional antenna 111 as well) comprising an antenna body 103 formed into a quadrangular flat board, the antenna body 103 being provided with two feeding points 103a, 103b of which phase difference is 90 degrees. In the third conventional antenna 111, line lengths L1, L2 of two wires formed between the external I/O terminal 107 as an interface to an external device and two feeding points 103a, 103b are determined to have different

lengths. In other words, the third conventional antenna 111 performs phase conversion of two signals inputted and outputted through different feeding points 103a, 103b by a difference of the line lengths L1, L2 (L2-L1) to eliminate the phase difference of the signals received in the antenna body 103. Then, it can input and output a combined signal into which the two signals after the phase conversion are combined to and from the external device. In the central position of the antenna body 103, an earth point 103c is provided which is electrically connected to a ground portion provided on the back face of the board via a through-hole formed piercingly through the board.

The third conventional antenna 111 constituted as such is more advantageous than the fourth conventional antenna 121 comprising the aforementioned circular antenna body 123 in that a frequency bandwidth of the radio wave which can be transmitted and received is wide.

For an antenna comprising the antenna body 103 on which the two feeding points 103a, 103b are formed, there is also an antenna 101 (hereinafter, referred to as a first conventional antenna 101 as well) comprising a phase converter 105 between the two feeding points 103a, 103b and the external I/O terminal 107, as shown in Fig. 5A. The phase converter 105 converts a plurality of signals of a different phase inputted from the outside into signals of an equal phase, and outputs a combined signal into which the plurality of signals after the phase conversion are

combined. The first conventional antenna 101 comprising the phase converter 105 can further expand the frequency bandwidth of the radio wave which can be transmitted and received compared to the third conventional antenna 111 which performs phase conversion by adjusting the line lengths of the lines formed between the feeding points 103a, 103b and the external I/O terminal 107. As a result, improvement in antenna characteristics can be achieved.

The first conventional antenna 101 comprising the phase converter 105, however, occupies a larger area, due to the presence of the phase converter 105, than the third conventional antenna 111 which does not comprise any phase converter. The larger the area occupied by an antenna is, the larger space for installing the antenna is necessary. Therefore, an antenna comprising a phase converter has limited uses depending on the installation space.

Moreover, since the antenna comprising the antenna body formed into a flat board is comparatively thin and requires only a small installation space, it tends to be included in a communication apparatus for transmitting and receiving data through a radio wave, for example. Among the communication apparatuses with a built-in antenna in the form of a flat board, there is a communication apparatus comprising a phase converter in order to transmit and receive a radio wave in a broader frequency bandwidth. However, such a communication

apparatus requires to an enlarge space for installation of the antenna due to the phase converter, and thus, grows in size.

As a example of the communication apparatus with a built-in antenna in the form of a flat board, there is an onboard device for use in an ETC (Electronic Toll Collection) system and an ERP (Electronic Road Pricing) system. Since such an onboard device is provided in a vehicle where the installation space is limited, there is a high demand for the miniaturization.

It is well-known that the position of the phase converter 105 arranged in relation to the antenna body 103 affects the antenna characteristics of the antenna body 103. In other words, the first conventional antenna 101 having the phase converter 105 arranged in a position adjacent to a corner of the quadrangular antenna body 103 (see Fig. 5A) has less influence to the antenna characteristics owing to the phase converter 105 than the second conventional antenna 109 having the phase converter 105 arranged in a position adjacent to a side of the quadrangular antenna body 103 (see Fig. 5B).

This is related to electric field distribution around the antenna body 103. In the electric field distribution, regions in the vicinity of the center of the sides of the quadrangle have high electric fields, and regions in the vicinity of the ends of the sides of the quadrangle have low electric fields. In order to minimize the influence to the electric field distribution, it is desirable that the phase converter 105 is arranged in the vicinity of a corner of

the quadrangle where the electric field is low. Since fluctuation in the electric field distribution influences the antenna characteristics, the phase converter 105 can be arranged in a position adjacent to a corner of the antenna body 103 where the electric field is low to repress the influence to the antenna characteristics.

However, comparing the area occupied by the antenna body 103 and the phase converter 105 in the first conventional antenna 101 to the area occupied by the same in the second conventional antenna 109, there is a relation of "A1 > A2" between the respective vertical dimensions, and of "B1 > B2" between the respective transverse dimensions. From the above, it is understood that the substantial area occupied by the first conventional antenna 101 (A1 × B1) is larger than the substantial area occupied by the second conventional antenna 109 (A2 × B2). Accordingly, the first conventional antenna 101, in which the phase converter 105 is arranged around the antenna body 103 in a position adjacent to a corner of the quadrangle (see Fig. 5A) in order to repress the influence to the antenna characteristics, occupies a further large area.

Additionally, the phase converter 105 of the first conventional antenna 101 is formed into a near rectangle. Therefore, the distance between the phase converter 105 and the antenna body 103 can be short in the central portion of the longitudinal length of the phase converter 105. However, the

distance is inevitably long in both end portions of the longitudinal length of the phase converter 105. In other words, wasted spaces are created between both end portions of the longitudinal length of the phase converter 105 and the antenna body 103, resulting in that the area occupied by the antenna as a whole is enlarged.

SUMMARY OF THE INVENTION

Embodiments of the present invention seek to provide an antenna comprising a phase converter, which can repress an influence by the phase converter to antenna characteristics of an antenna body as well as reduce an area occupied by the antenna, and to provide also a phase converter for realizing the antenna and a communication apparatus constituted using the antenna.

According to a first aspect of the present invention, there is provided an antenna for transmitting and receiving a radio wave, comprising: an antenna body for a circularly polarized wave which is formed into a quadrangular flat board constituted from an electric conductor and which outputs reception signals of a different phase respectively from two feeding points; and a phase converter which converts the two signals of a different phase inputted from the respective feeding points of the antenna body into signals of an equal phase and outputs a combined signal into which the two signals are combined, wherein the phase converter is formed into a near V-shape corresponding to a shape in the vicinity of a corner portion of the quadrangular antenna body, and is arranged on nearly the same plane as the antenna body so that the inner vertex of the nearly V-shaped portion faces the corner portion of the quadrangular antenna body.

The antenna body outputs reception signals of a different phase from two feeding points, respectively. The phase converter converts the two signals of a different phase inputted from the respective feeding points of the antenna body into signals of an equal phase, and outputs a combined signal into which the two signals are combined.

In other words, since the phase converter is formed into a near V-shape corresponding to the shape in the vicinity of the corner portion of the quadrangular antenna body, it can be arranged adjacent to the antenna body. The antenna comprising such a phase converter can prevent creation of wasted spaces between the phase converter and the antenna body. Accordingly, by eliminating the possible wasted spaces, the substantial area occupied by the antenna body and the phase converter can be reduced, and miniaturization of the antenna can be realized.

The expression "the antenna body and the phase converter are arranged on nearly the same plane" means not only that they are arranged on exactly the same plane, but also that the antenna body is formed on one side of a flat member (e.g. the board) and the phase converter is formed on the back side of the board. In other words, the antenna comprising the antenna body and the phase converter arranged side by side with a slight

interval between (e.g. the thickness of the board) is regarded within a technical scope of the present invention. When the antenna body and the phase converter are arranged side by side with the board between, the relative position of the antenna body to the phase converter may be determined so that the inner vertex of the nearly V-shaped portion of the phase converter faces a corner of the quadrangular antenna body when looked through the flat board toward the perpendicular direction.

Furthermore, since embodiment of the antenna of the present invention is adapted to arrange the phase converter in the vicinity of a corner of the quadrangular antenna body, the influence to electric fields around the antenna body can be reduced and the influence to the antenna characteristics by the phase converter can be repressed.

Accordingly, embodiment of the antenna of the present invention, even when provided with the phase converter, can repress the influence to the antenna characteristics of the antenna body by the phase converter as well as reduce the occupied area.

It is preferable that the antenna body is formed into a square of which length and breadth are the same in order to transmit and receive a radio wave in good condition. The antenna body in the form of a square allows the frequency bands of radio waves detected in the respective vertical and transverse directions to be conformed to each other, and thereby transmission and reception of the circularly polarized wave can

be performed with precision.

In order to arrange the antenna body and the phase converter in predetermined positions, the antenna body and the phase converter may be fixed respectively onto a medium member made of an insulated material, which fits into the space between the antenna body and the phase converter, for example.

For another example, the phase converter and the antenna body may be formed on the same board so that the inner vertex of the nearly V-shaped portion of the phase converter faces to a corner of the quadrangular antenna body.

In other words, since the antenna body is formed into a flat board, the attachment of the antenna body to the board is simple. Moreover, since the antenna body and the phase converter are fixed on the same board, relative positioning of both devices can be easy compared to a case where both devices are fixed on separate boards. Therefore, complicated operations for producing the antenna are eased.

Accordingly, embodiments of the present invention enable easy arrangement of the antenna body and the phase converter to target positions, thereby allowing miniaturization of the antenna, and also represses fluctuation of the antenna characteristics. Additionally, since the complicated operations for producing the antenna can be dissolved, production efficiency per unit of time can be improved, and accordingly, costs for producing the antenna can be reduced.

When the antenna body and the phase converter are fixed on separate boards, the relative position of the antenna body to the phase converter may change due to the position change of one of the boards. Then, there is a fear that the phase converter may be moved to a position where the antenna characteristics are lowered. Embodiments of the present invention prevent the relative position of the antenna body to the phase converter from changing by fixing both devices on the same board. Consequently, lowering of the antenna characteristics can be prevented.

It is preferable that the board is made of a material which does not influence the high frequency characteristic of the antenna body. Then, fluctuation of the antenna characteristics by the board can be prevented. Such a board is expensive. However, embodiment of the antenna of the present invention can reduce the substantial occupied area. Therefore, consumption of the board can be reduced compared to before, and cost reduction can be achieved.

It is preferable that a large space is provided between the antenna body and the phase converter in order to repress the influence to the antenna characteristics. Therefore, the antenna body may be fixed on one side and the phase converter may be fixed on the other side of a board. In this manner, the space between the antenna body and the phase converter is enlarged and fluctuation of the antenna characteristics can be

repressed. Accordingly, transmission and reception of radio waves in good condition can be achieved. In this case, it is preferable that the relative position of the antenna body to the phase converter is determined so that the inner vertex of the nearly V-shaped portion of the phase converter faces a corner of the quadrangular antenna body, when looked through the board toward the perpendicular direction.

A phase converter 105 (see Fig. 6B) is constituted from an electric conductor forming a nearly rectangular circular line. Four I/O ports are provided in positions dividing the line extending to the circumference of the electric conductor into four separate sections so that the respective intra-line wavelengths are equal to "$\lambda g / 4$". (λg is an intra-line wavelength of a radio wave transmitted and received). The intra-line wavelength does not mean a wavelength in a free space but a wavelength of a signal within a transmission line.

The four I/O ports includes first and second I/O ports 105e and 105f through which two signals of a different phase are inputted, a third I/O port 105g through which a combined signal is outputted, and a fourth I/O port 105h which is connected to a resistor element having a resistance value equivalent to the input impedance of an external line to which the third I/O port is connected. In this case, the first and the second I/O ports 105e and 105f are next to each other, and the third and the fourth I/O ports 105g and 105h are next to each other. A first line 105a

formed between the first and the second I/O ports 105e and 105f and a third line 105c formed between the third and the fourth I/O ports 105g and 105h are formed respectively to have an equal line width (W1=W2).

The phase converter 105 converts two signals of a different phase which are inputted from the first and the second I/O ports 105e and 105f into signals of an equal phase, and outputs a combined signal into which two signals after the phase conversion are combined to the third I/O port 105g.

A phase converter to be provided with the antenna of the present invention must be in a near V-shape. However, if the aforementioned phase converter constituted from the electric conductor forming a nearly rectangular circular line is bent in the middle of a pair of lines corresponding to the longitudinal length of the near rectangle (the first and the third lines 105a and 105c), the nearly V-shaped phase converter can be realized. In this case, the first and the second I/O ports to which two signals of a different phase are respectively inputted are formed on the inner line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the center of the bent portion. The third and the fourth I/O ports are formed on the outer line of the nearly V-shaped portion of the electric conductor in positions symmetric with respect to the center of the bent portion.

However, simply bending the nearly rectangular phase

converter causes the line lengths in the inner and the outer lines of the bent portion to be different. In other words, the line between the first and the second I/O ports and the line between the third and the fourth I/O ports are formed to have different line lengths. As a result, the line lengths between the respective I/O ports are different, and the phase conversion quantities and passage losses are affected due to the unbalanced intra-line wavelength and impedance between the I/O ports of the two signals. Consequently, neither appropriate phase conversion nor combination can be performed to the two signals of a different phase.

In the antenna according to embodiments of the present invention, the phase converter is constituted from an electric conductor forming a long circular line which is bent in the middle to form a near V-shape. The first and the second I/O ports to which two signals of a different phase are inputted are formed on the inner line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the center of the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of a radio wave transmitted and received by the antenna. The third I/O port from which the combined signal is outputted and the fourth I/O port connected to a resistor element having a resistance value equivalent to the input impedance of the outer line to which the third I/O port is connected are formed on the outer line of the nearly V-shaped

bent portion of the electric conductor in positions symmetric with respect to the center of the bent portion and in positions where the length between the ports is about one fourth of the waveform λg of the radio wave transmitted and received by the antenna. The width of the line between the first and the second I/O ports and the width of the line between the third and the fourth I/O ports are determined so that the two signals inputted to the first and the second I/O ports have an almost equal passage loss.

Such an arrangement of the I/O ports allows the nearly V-shaped phase converter to convert two signals of a different phase into signals of an equal phase as well.

Furthermore, since the width of the line between the first and the second I/O ports and the width of the line between the third and the fourth I/O ports are determined so that the two signals inputted to the first and the second I/O ports have an equal passage loss, a combined signal into which the two signals after the phase conversion are appropriately combined can be outputted.

The intra-line wavelength and impedance between the I/O ports of the two signals can be adjusted by forming the inner and the outer lines of the nearly V-shaped bent portion to have different line widths, for example. In this manner, by adjusting the line widths of the respective lines, it is possible to convert two signals of a different phase to signals of an equal phase, adjust the passage losses of the two signals to be equal, and

output a combined signal into which the two signals after the phase conversion are appropriately combined, in the nearly V-shaped phase converter.

The line width of the inner line of the bent portion is set to have the impedance "$0.9Z_0$" and the line width of the outer line of the bent portion is set to have the impedance "$1.25Z_0$" where Z_0 is the input impedance of the external line.

Adjustment of the respective phase conversion quantities and passage losses of two signals of a different phase can be also performed by adjusting the intra-line wavelengths of the lines formed between the first or the second I/O port and the third or the fourth I/O port. For example, when the first and the third I/O ports are next to each other, the line length may be set so that the intra-line wavelength in the line between the first and the third I/O ports is equal to "$\lambda g / 3.23$".

The conversion point of the line width (that is, the impedance conversion point) in the circular line is not limited to the portion where each of the I/O ports is formed.

Accordingly, embodiments of the present invention enable two signals of a different phase to have an equal passage loss and also enables the signals to be converted into signals of an equal phase even when the nearly rectangular phase converter is transformed into a near V-shape. As a result, it is possible to output a combined signal into which the two signals after the phase conversion are appropriately combined.

According to a second aspect of the present invention, there is provided a phase converter for converting two signals of a different phase inputted from the outside to signals of an equal phase and outputting a combined signal into which the two signals after the phase conversion are combined,

the phase converter being an electric conductor forming a long circular line which is formed into a near V-shape bent in the middle of the longitudinal length,

first and second I/O ports into which the two signals of a different phase are inputted being formed on the inner line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of the signal inputted from the outside,

a third I/O port from which said combined signal is outputted and a fourth I/O port connected to a resistor element having a resistance value equivalent to the input impedance of an external line to which the third I/O port is connected being formed on the outer line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of the signal inputted from the outside,

a line width between the first and the second I/O ports and a line width between the third and the fourth I/O ports being determined so that the two signals inputted to the first and the second I/O ports have an equal passage loss.

This phase converter can be used for other purposes besides the aforementioned antenna. It can be advantageous when it is difficult to arrange the conventional nearly rectangular phase converter due to a narrow space. It can also perform appropriate phase conversion to two signals of a different phase, transmit the signals having an equal passage loss, and perform appropriate signal combination.

In another aspect of the present invention, a communication apparatus for transmitting and receiving data to and from the outside using a radio wave is provided, which comprises the aforementioned antenna for transmitting and receiving the radio wave.

In other words, the aforementioned antenna allows miniaturization in comparison to the conventional antenna. Therefore, the communication apparatus of the present invention can reduce the installation space, and realize miniaturization of the whole apparatus.

Since the aforementioned antenna can control fluctuation of the antenna characteristics, the communication apparatus of the present invention can transmit and receive the radio wave to and from the outside in good condition, and perform precise data transmission and reception.

An example of the communication apparatus comprising the antenna is an onboard device for an ETC and ERP system. Since such an onboard device is mounted on a vehicle with a

limited space, there is a high demand for miniaturization. Miniaturization of the onboard device is possible by constituting the same with the antenna of the present invention. In addition to the miniaturization, it can repress the influence to the antenna characteristics, and accordingly, precise data transmission and reception can be performed.

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1A is a schematic diagram of an ERP onboard device, and Fig. 1B is a schematic diagram of an antenna face of an RF board;

Fig. 2 is a circuit diagram of the respective devices fitted to the RF board;

Fig. 3 is an explanatory view showing a schematic constitution of a digital board and various devices connected to the digital board;

Figs 4A-4D are explanatory views of other embodiments relating to arrangement of an antenna body and a phase converter to the board, where Fig. 4A shows the antenna body and the phase converter arranged on the same plane, Fig. 4B shows the antenna body turned by 45 degrees, Fig. 4C shows the antenna body turned by 45 degrees and the phase converter arranged on a different face when looked from an antenna face,

and 4D shows the antenna body turned by 45 degrees and the phase converter arranged on the different face when looked from a part face;

Fig. 5A is a schematic diagram of a first conventional antenna comprising an antenna body formed into a quadrangular flat board and a phase converter arranged in the vicinity of a corner portion of the quadrangle, Fig. 5B is a schematic diagram of a second conventional antenna comprising an antenna body formed into a quadrangular flat board and a phase converter arranged in the vicinity of a side of the quadrangle, Fig. 5C is a schematic diagram of a third conventional antenna which comprises an antenna body formed into a quadrangular flat board and performs phase composition of two signals by setting line lengths of two wires to be different, and Fig. 5D is a schematic diagram of a fourth conventional antenna comprising an antenna body formed into a nearly circular flat board;

Fig. 6A is an enlarged view of a nearly V-shaped phase converter in an embodiment of the present invention, and Fig. 6B is an enlarged view of a nearly rectangular phase converter in the prior art;

Figs. 7A-7D show measurement results concerning a passage loss of a signal in the phase converter, where Fig. 7A is of a first measurement, Fig. 7B is of a second measurement, Fig. 7C is of a reference measurement, and Fig. 7D is of a third measurement;

Figs. 8A-8C show measurement results concerning a phase of an output signal in the phase converter, where Fig. 8A is of a first measurement, Fig. 8B is of a reference measurement, and Fig. 8C is of a third measurement; and

Fig. 9 is a schematic diagram of an antenna which can transmit and receive right-handed and left-handed circularly polarized radio waves.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Fig. 1A is a schematic diagram of an ERP (Electronic Road Pricing) onboard device 1 according to the present invention. The ERP onboard device is a communication apparatus which is mounted on a vehicle and transmits and receives a radio wave to and from a road side device located on roads, etc.

As shown in Fig. 1A, the ERP onboard device 1 comprises an RF board 11, a digital board 13 and a display portion (LCD circuit board 15). The RF board 11 and the digital board 13 are connected via a first communication cable CA1, and the digital board 13 and the LCD circuit board 15 are connected via a second communication cable CA2. The ERP onboard device 1 is also provided with a card holder and a buzzer, which are not shown in Fig. 1A. The card holder is connected to the digital board 13 via a third communication cable, and the buzzer is connected to the digital board 13 via a fourth communication cable.

The RF board 11 is a PTFE (polytetrafluoroethylene) or BT (Bsmaleimide-Triazine) resin RF board provided with a part face and an antenna face. A phase converter 23 (also referred to as a coupler) and a signal conversion circuit 25 are attached on the part face, and an antenna body 21 is attached on the antenna face opposite to the part face. Fig. 1A shows a schematic diagram in the part face of the RF board 11, and Fig. 1B shows a schematic diagram in the antenna face of the RF board 11. The antenna body 21 and the phase converter 23 constitute an antenna 20.

Details of the respective devices attached to the RF board 11 are explained by way of a circuit diagram of the devices attached to the RF board, shown in Fig. 2.

The antenna body 21 is formed into a square flat board constituted from an electric conductor. It has two feeding points 21a, 21b which output signals of a different phase detected from the received radio wave. In the center of the antenna body 21, an earth point 21c electrically connected with a ground portion provided on the back of the board via a through-hole formed piercingly through the board is provided. The antenna body 21 is adapted to receive an ASK (Amplitude shift keying) signal of 2.40-2.44GHz transmitted from a tollgate antenna (a road side device) and to transmit a PSK (Phase shift keying) signal of 2.40-2.44GHz. The antenna body 21 is constituted from a patch antenna using a microstrip line, and transmits and receives a

right-handed circularly polarized wave. The antenna body 21 uses a half-duplex communication as a wireless transmission method.

The phase converter 23 converts two signals Sa, Sb of a different phase inputted from the first and second feeding points 21a, 21b of the antenna body 21 into signals of an equal phase, and outputs a combined signal Sm into which the two signals Sa, Sb after the phase conversion are combined.

As shown in Fig. 1B, an interval P1 between the antenna body 21 and the phase converter 23 when looked through to a direction of the radio wave transmission and reception is set at 3.9 mm, which is shorter than a length ($\lambda g / 16$) where λg is an intra-line wavelength of the transmitted and received radio wave.

Fig. 6A shows an enlarged view of the phase converter 23.

As shown in Fig. 6A, the phase converter 23 is constituted from an electric conductor forming a nearly elliptic line bent in the middle of the longitudinal length to form a near V-shape. First and second I/O ports 23e and 23f are formed on the inner line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the center of the bent portion, and third and fourth I/O ports 23g and 23h are formed on the outer line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the center of the bent portion.

A first line 23a is formed between the first and the second I/O ports 23e and 23f, a second line 23b is formed between the second and the third I/O ports 23f and 23g, a third line 23c is formed between the third and the fourth I/O ports 23g and 23h, and a fourth line 23d is formed between the fourth and the first I/O ports 23h and 23e.

In other words, the phase converter 23 is formed into a near V-shape as the result that the first and the third lines 23a and 23c are bent in the middle to form a vertex of the V-shape.

A line width W1 of the first line 23a between the first and the second I/O ports 23e and 23f and a line width W2 of the third line 23c between the third and the fourth I/O ports 23g and 23h are formed to have different lengths. In other words, the line width W1 is determined so that the impedance of the first line 23a is $(0.9Z_0)$ and the line width W2 is determined so that the impedance of the third line 23c is $(1.25Z_0)$ where Z_0 is the input impedance of an external line. Specifically, while the input impedance Z_0 of the external line is 50Ω, the line width W1 is set so that the impedance of the first line 23a is 45Ω, and the line width W2 is set so that the impedance of the third line 23c is 62.5 Ω.

The line lengths of the first line 23a and the third line 23c of the phase converter 23 are set so that $L3 = (\lambda g / 4)$ where L3 is the respective intra-line wavelength. The line lengths of the second line 23b and the fourth line 23d are set so that $L4 = (\lambda g /$

3.23) where L4 is the respective intra-line wavelength. A conversion point of the line width in a circular line (that is, an impedance conversion point) is formed in a position different from portions where the respective I/O ports are formed.

As shown in Fig. 2, the first I/O port 23e is connected to the first feeding point 21a of the antenna body 21, the second I/O port 23f is connected to the second feeding point 21b of the antenna body 21, the third I/O port 23g is connected to a filter circuit 27 of the signal conversion circuit 25, and the fourth I/O port 23h is grounded via a dummy resistance R1.

The phase converter 23 constituted as above performs phase conversion of the first signal Sa inputted to the first I/O port 23e and the second signal Sb inputted to the second I/O port 23f so that both signals have an equal phase, and outputs the combined signal Sm into which the two signals Sa, Sb after the phase conversion are combined. Since both first and second signals Sa and Sb have an almost equal passage loss, the phase converter 23 can output a combined signal into which the first and the second signals Sa and Sb are appropriately combined. In other words, the phase converter 23 can output the combined signal without influencing the cross polarization characteristic and axial ratio when performing phase conversion and combination of the first and the second signals Sa and Sb which are circularly polarized wave signals.

The signal conversion circuit 25, as shown in Fig. 2,

comprises the filter circuit 27, a FET (field-effect transistor) 29, a reception signal demodulation circuit 31, an open stab ST, a received data amplification circuit 33, a reception signal level adjustment circuit 35, a received data amplification circuit 37 and a reception signal detection circuit 39.

The filter circuit 27 extracts a signal element corresponding to a predetermined frequency band (2.40-2.44GHz) from a signal detected from the radio wave received and transmitted in the antenna 20.

The FET 29 is set in one of the ON and the OFF states according to a TX data signal transmitted from the digital board 13. When the FET 29 is in the ON state, the reception signal is passed through the FET 29 to be reflected in the open stab ST, and the reflected signal is again passed through the FET 29 to be outputted from the antenna body 21 to the outside. When the FET 29 is in the OFF state, the reception signal is reflected in the FET 29, and the reflected signal is outputted from the antenna body 21 to the outside. In this manner, since the line length along which the reflected signal travels is different depending on the state of the FET 29, it is possible to cause a phase difference to the reflected signal outputted from the antenna body 21 and output a PSK signal. When a signal is received, the FET 29 is turned to the ON state, and the reception signal is passed through the FET 29 to be demodulated in the later-explained reception signal demodulation circuit 31.

The reception signal demodulation circuit 31 is constituted from a diode DI, and by directly detecting and demodulating the reception signal (2.40-2.44GHz) with the diode DI, extracts data included in the radio wave. The open stab ST reflects the reception signal to be transmitted toward the antenna body 21, and is used for generation of the aforementioned PSK signal. The signal conversion circuit is biased such that when the FET 29 is in the ON state, the diode DI is also in the ON state, and when the FET 29 is in the OFF state, the diode DI is also in the OFF state.

The received data amplification circuit 33 comprises an amplifier, by which the demodulated data in the reception signal demodulation circuit 31 is amplified about 40dB.

The reception signal level adjustment circuit 35 is provided for absorbing a difference in reception signal levels caused by variance of characteristics (individual difference) of the reception signal demodulation circuit 31, received data amplification circuit 33 and the later explained received data amplification circuit 37. The reception signal level adjustment circuit 35 comprises a variable register VR and two resistor elements 35a, 35c, and absorbs the difference in the reception signal levels caused by the variance of characteristics (individual difference) by adjusting a resistance value of the variable register VR. In the reception signal level adjustment circuit 35, a thermistor 35b is connected side by side with the resistor

element 35c in order to compensate fluctuation in the reception signal levels by a difference in temperature in addition to the difference in the reception signal levels caused by the variance of characteristics.

The received data amplification circuit 37 comprises an amplifier 37a and an inverter 37b. Similar to the received data amplification circuit 33, it amplifies the data demodulated in the reception signal demodulation circuit 31 by way of the amplifier 37a. It amplifies the gain which is short in the received data amplification circuit 33. The inverter 37b inverts the signal level of a signal outputted from the amplifier 37a to generate a RX data signal, and outputs the RX data signal to the digital board 13 via the first communication cable CA1. The inverter 37b adjusts and outputs the RX data signal so that a current value and a voltage value of the RX data signal are within a defined current value and a defined voltage value in an input terminal of a later explained CPU 41 provided on the digital board 13.

The reception signal detection circuit 39 comprises an operation amplifier 45, two resistor elements 45a, 45b and an inverter 47. The operation amplifier 45 compares a voltage of the reception signal detected in the reception signal demodulation circuit 31 with a reference voltage determined in two resistor elements 45a, 45b. When the voltage level of the reception signal is higher than the reference voltage, the

operation amplifier 45 outputs an output signal at high level, and when the voltage level of the reception signal is lower than the reference voltage, it outputs an output signal at low level. The inverter 47 outputs an RX detection signal, which is the output signal outputted from the operation amplifier 45 of which level is inverted, to the digital board 13 via the first communication cable CA1. The inverter 47 adjusts and outputs the RX detection signal so that a current value and a voltage value of the RX detection signal is within a defined current value and a defined voltage value in the input terminal of the later explained CPU 41 provided on the digital board 13.

The reception signal detection circuit 39 performs a detection process of the reception signal periodically. In case that the detection of the reception signal by the reception signal detection circuit 39 is not performed for a certain period of time; the later explained CPU 41 provided on the digital board 13 shifts the ERP onboard device 1 to the wait state. When the ERP onboard device 1 is in the wait state, a power saving switching signal is inputted from the digital board 13 to the signal conversion circuit 25. Inside the signal conversion circuit 25, a not shown power saving control circuit operates according to the power saving switching signal and supplies power only to the reception signal detection circuit 39 to lower power consumption.

When the reception signal detection circuit 39 detects the

reception signal in the wait state and outputs the RX detection signal, the CPU 41 shifts the ERP onboard device 1 to the normal state and starts supplying power to each portion. Power is supplied to the respective devices included in the signal conversion circuit 25 via a power supply line in the first communication cable CA1.

The digital board 13 is now explained by way of a schematic diagram shown in Fig. 3.

As can be seen from Fig. 3, the digital board 13 comprises the CPU 41, a reference oscillation circuit 51 and a power control portion 43.

The CPU 41 takes in the reception signal (RX data signal) from the RF board 11 (more particularly, received data amplification circuit 37) via the first communication cable CA1, and extracts information such as on an onboard device validation signal, a toll, a position of a tollgate, etc. The CPU 41 outputs a transmission signal (TX data signal) including the onboard device validation signal, vehicle information, IC card information, etc. to the RF board 11 (more particularly, FET 29) via the first communication cable CA1. The CPU 41 comprises a memory (not shown) for accumulating information such as a name of the owner of the onboard device, vehicle data, tolls paid, dates, time, etc.

The reference oscillation circuit 51 comprises a crystal oscillator, etc., for example, and outputs a reference clock signal

to the CPU 41.

The power control portion 43 comprises a voltage conversion portion 43a and a switch 43b. It performs appropriate voltage conversion of a voltage (9-24V) supplied from a power unit BT (battery) provided in the vehicle to supply power in a voltage suitable for operations of the respective portions. In the vehicle, the noise such as an ignition noise is generated. However, the voltage conversion portion 43a of the power control portion 43 comprises a coil, a condenser, a filter, etc. for removing the noise, and it prevents the noise from affecting to the portion to which the power is supplied.

To the digital board 13, a display portion 15 is connected via the second communication cable CA2, the card holder 53 is connected via the third communication cable CA3, and a buzzer 55 is connected via the fourth communication cable CA4.

The display portion 15 displays various information such as the toll, tolls paid, insertion state of an IC card, position of the tollgate, etc. according to a display instruction signal from the CPU 41 to provide the information to the user. An IC card 57 can be fitted into the card holder 53. The card holder 53 reads and updates the IC card information included in the IC card 57 according to an IC card operation instruction signal from the CPU 41. The buzzer 55 gives an alarm to the user according to a sound output instruction signal from the CPU 41.

In the ERP onboard device 1 constituted as such, the

phase converter 23 is formed into a near V-shape corresponding to a shape in the vicinity of a corner portion of the quadrangular antenna body 21, and the phase converter 23 and the antenna body 21 are arranged on the same RF board 11 so that the inner vertex of the nearly V-shaped portion of the phase converter 23 faces the corner of the quadrangular antenna body 21, as can be seen from Figs. 1A and 1B.

In other words, since the phase converter 23 is formed into a near V-shape corresponding to a corner portion of the quadrangular antenna body 21, it can be arranged close to the antenna body 21, narrowing an interval between the antenna body 21 and the phase converter 23. The antenna 20 comprising such a phase converter 23 according to the present embodiment can prevent forming wasted spaces between the phase converter 23 and the antenna body 21. Accordingly, by eliminating wasted spaces, the substantial area occupied by the antenna body 21 and the phase converter 23 can be reduced and the antenna 20 can be minimized.

Additionally, since the phase converter 23 is arranged in the vicinity of a corner of the quadrangular antenna body 21, the influence to electric fields around the antenna body 21 can be reduced. Consequently, the influence to the antenna characteristics of the antenna body 21 by the phase converter 23 can be repressed.

Accordingly, the antenna 20 provided with the ERP

onboard device 1 of the present embodiment can not only repress the influence to the antenna characteristics of the antenna body 21 by the phase converter 23, but also reduce the occupied area.

Since the antenna body 21 is formed into a square of which length and breadth are the same, the frequency bands of the radio waves detected in the vertical and transversal directions can be conformed to each other. Therefore, transmitting and receiving of the circularly polarized wave can be performed more precisely.

Also, since the antenna body 21 is formed into a flat board, the attachment to the RF board 11 is easy. By fixing the antenna body 21 and the phase converter 23 on the same board, it is easier to determine the relative position of the antenna body 21 to the phase converter 23 than a case in which both devices are fixed on separate boards. Therefore, complicated operations for producing the antenna becomes simple.

According to the antenna 20 of the present embodiment, easy arrangement of the antenna body 21 and the phase converter 23 to target positions is possible. Moreover, the antenna 20 itself can be miniaturized, and fluctuation of the antenna characteristics can be repressed. Additionally, since complicated operations for producing the antenna 20 can be dissolved, the production efficiency per unit of time is improved and the costs for producing the antenna 20 can be reduced.

When the antenna body and the phase converter are fixed

on separate boards, there is a fear that the relative position of the antenna body to the phase converter are changed due to the change of position of either of the boards and that the phase converter is moved to a position where the antenna characteristics are lowered. If the antenna body 21 and the phase converter 23 are fixed on the same RF board 11 as in the present embodiment, the relative position of the antenna body 21 to the phase converter 23 is not changed and lowering of the antenna characteristics is prevented.

The RF board 11 is a PTFE or BT resin RF board which does not affect a high frequency characteristic of the antenna body 21. Therefore, fluctuation of the antenna characteristics by the RF board 11 can be repressed. The material used for the PTFE or BT resin RF board is expensive. However, since the substantial occupied area can be reduced, the consumption is lowered compared to before, and thereby cost reduction is possible.

In the antenna 20 of the present embodiment, the antenna body 21 is fixed on one side of the RF board 11 and the phase converter 23 is fixed on the other side of the RF board 11. Compared to a case of fixing both devices on the same side, it is possible to provide a longer distance between the antenna body 21 and the phase converter 23. Thereby, fluctuation of the antenna characteristics can be repressed and satisfactory transmission and reception of the radio wave can be realized.

The phase converter 23 can perform phase conversion so that the first and the second signals Sa and Sb have an equal phase. Also, since the first and the second signals Sa and Sb have an almost equal passage loss, a combined signal into which the first and the second signals Sa and Sb are appropriately combined can be outputted. In other words, the phase converter 23 not only allows the antenna 20 to be miniaturized, but also maintains a function of converting two signals of a different phase into signals of an equal phase and outputting the signals as a combined signal.

The ERP onboard device 1 comprising the antenna 20 which can be miniaturized requires a smaller installation space for the antenna 20 on the RF board 11 compared to before, thereby allowing miniaturization of the whole device. Moreover, since the antenna 20 can repress fluctuation of the antenna characteristics by the phase converter 23, the ERP onboard device 1 can transmit and receive the radio wave to and from the outside in good condition and precise transmission and reception of data can be performed.

As a result, the ERP onboard device 1 of the present embodiment can improve mountability on a vehicle owing to the miniaturization, and realize a stable ERP system owing to the improvement in precision of data transmission and reception.

Here, measurements performed to confirm that two signals of a different phase can be appropriately combined by

setting the inner and the outer lines of the nearly V-shaped bent portion of the phase converter to have different line widths are explained.

Two signals of an equal phase were respectively inputted to first and second I/O ports of a phase converter, and the phase and the passage loss of an output signal from a third I/O port were measured.

In the present measurements of the phase and the passage loss, two types of nearly V-shaped phase converters, as shown in Fig. 6A, of which line width W1 of the first line 23a and the line width W2 of the third line 23c are different, and a phase converter of which line width W1 is the same with the line width W2 are used. Specifically, the first measurement using a phase converter of which line width W1 = 2.36mm and the line width W2 = 1.50mm, the second measurement using a phase converter of which line width W1 = 2.36mm and the line width W2 = 1.34mm, and the third measurement using a phase converter of which line width W1 = 2.36mm and the line width W2 = 2.36mm were performed.

The impedance of the line with the line width 2.36mm is 45.3Ω, the impedance of the line with the line width 1.50mm is 59.0Ω, and the impedance of the line with the line width 1.34mm is 62.6Ω. The intra-line wavelength L3 of the first and the third lines 23a and 23c is determined so that L3 = (λg / 4), and the intra-line wavelength L4 of the second and the fourth lines

23b and 23d is determined so that L4 = (λ g / 3.23). The impedance in the second and the fourth lines 23b and 23d is 37.4 Ω.

As a comparison, a measurement (reference measurement) of the phase and the passage loss of the nearly rectangular phase converter 105 as shown in Fig. 6B is also performed. Specifically, the phase converter 105 of which line width W1 of the first line 105a and line width W2 of the third line 105c are equal to 2.00mm is used. The impedance of the line with the line width 2.00mm is 50.0 Ω. In the phase converter 105 for the reference measurement, all the intra-line wavelength L5 of the first, the second, the third and the fourth lines 105a, 105b, 105c and 105d is determined so that L5 = (λ g / 4). The impedance in the second and the fourth lines 105b and 105d is 35.4Ω.

Figs. 7A-7D show the measurement results with respect to the passage loss, and Figs. 8A-8C show the measurement results with respect to the phase. Fig. 7A shows the result of the first measurement, Fig. 7B shows the result of the second measurement, Fig. 7C shows the result of the reference measurement, and Fig. 7D shows the result of third measurement. Fig. 8A shows the result of the first measurement, Fig. 8B shows the result of the reference measurement, and Fig. 8C shows the result of the third measurement. In Figs 7A-7D and 8A-8C, the measurement

result of the first signal inputted from the first I/O port is shown by a line A, and the measurement result of the second signal inputted from the second I/O port is shown by a line B.

Referring to the measurement results of the passage loss shown in Figs. 7A-7D, two signals in the first and the second measurements had a practically equal passage loss. Accordingly, it is understood that the phase converters used in the first and the second measurements can output two signals with an almost equal passage loss and combine them appropriately. Specifically, in the phase converter in the second measurement, the passage losses of the two signals showed an almost equal value, and the performance is almost equal to the phase converter used in the reference measurement. Therefore, it is considered that the phase converter in the second measurement can combine two signals more precisely. On the other hand, the measurement result in the third measurement shows a large difference between the respective passage losses of the two signals. Therefore, it is considered that the phase converter in the third measurement has an adverse effect to the cross polarization characteristic and axial ratio.

Referring to the measurement results shown in Figs. 8A-8C, a phase difference between the two output signals (C1 + D1) is about 90 degrees in the first measurement. Therefore, it is understood that the result equivalent to the phase difference in the reference measurement (C2 + D2) can be obtained. Also in

the third measurement, the phase difference (C3 + D3) is about 90 degrees, and the result equivalent to the phase difference in the reference measurement can be obtained.

In view of the measurement results of Figs. 7A-7D and 8A-8C, it is understood that even in the phase converter formed into a near V-shape, the equivalent phase conversion quantity and passage loss to the conventional nearly rectangular phase converter can be realized by setting the line widths W1 and W2 to have different values. Additionally, according to the other measurement results performed by the inventors, it is found that setting the line width W1 so that the impedance is $0.9Z_0 \pm 10\%$ and the line width W2 so that the impedance is $1.25Z_0 \pm 20\%$ where Z_0 is the impedance of an external line connected to the phase converter enables the nearly V-shaped phase converter to realize the phase conversion quantity and passage loss practically equivalent to those of the conventional phase converter. By setting the intra-line wavelength in the second and the fourth lines 23b and 23d to be (λg / 3.23), more suitable phase conversion quantity and passage loss can be realized.

The present invention should not be limited to the described embodiments, and other modifications and variations might be possible without departing from the scope of the invention.

For instance, the antenna body 21 and the phase converter 23 are not necessarily attached to the sides opposed to

each other of the RF board 11. They may be arranged on the same side of the RF board 11 as shown in Fig. 4A. In addition, the antenna body 21 is not necessarily attached to the RF board 11 so that the respective sides are positioned side by side to each other. The antenna body 21 may be attached to the RF board 11 by turning the antenna body 21 about 45 degrees, as shown in Fig. 4B. In this case, the phase converter 23 changes its position in accordance with the turn of the antenna body 21 so that the inner vertex of the nearly V-shaped portion faces to a corner of the quadrangular antenna body 21. In this manner, the antenna body 21 and the phase converter 23 can be arranged without creating wasted areas on the board, and accordingly, it is possible to mount other devices in an efficient manner.

In Fig. 4B, the antenna body 21 and the phase converter 23 are attached on the same sides of the RF board 11. However, the antenna body 21 and the phase converter 23 may be attached on the sides opposite to each other of the RF board 11 as shown in Figs. 4C and 4D. Fig. 4C shows a schematic diagram of the RF board 11 when looked from the antenna face, and Fig. 4D shows a schematic diagram of the RF board 11 when looked from the part face.

In the above embodiment, the phase converter is a branch line type hybrid circuit (3dB directional coupler). However, the phase converter may be a rat race type or hybrid ring type hybrid circuit. Types of the hybrid circuit (3dB directional coupler) are

described in detail in "Microwave Circuit for Communication (Institute of Telecommunications Engineers, Corona Publishing Co., Ltd.).

The above embodiment describes the antenna for transmitting and receiving a right-handed circularly polarized wave. However, the antenna of the present invention can be used as an antenna for a left-handed circularly polarized wave. The antenna for left-handed circularly polarized wave can be realized by connecting the third I/O port 23g of the phase converter 23 to the dummy resistance and connecting the fourth I/O port 23h to the signal conversion circuit 25.

As shown in Fig. 9, by providing a second signal conversion circuit 26 similarly constituted to the signal conversion circuit 25, instead of the dummy resistance, and by connecting the second signal conversion circuit 26 to the digital board 13, an antenna 61 which can transmit and receive both right-handed and left-handed circularly polarized waves can be constituted. In this case, the signal conversion circuit 25 performs signal conversion of a signal by a right-handed circularly polarized wave, and the second signal conversion circuit 26 performs signal conversion of a signal by a left-handed circularly polarized wave. The digital board 13 is constituted to comprise an interface for connection with the second signal conversion circuit 26, and the CPU of the digital board 13 is constituted to perform a process for transmitting and receiving

various information to and from the outside based on the signals respectively by right-handed and left-handed circularly polarized waves.

In the above embodiment, the phase converter 23 (see Fig. 6A) of which line widths W1 and W2 respectively of the first and the third lines 23a and 23c are different is described. However, even if the line widths W1 and W2 are different, the antenna of the present invention can be realized by using a phase converter constituted so that two signals leading to the combined signal have an almost equal passage loss. For instance, even if the phase converter shown in Fig. 6A has the first and the third lines 23a and 23c of which line widths W1 and W2 are the same, and the second and the fourth lines 23b and 23d of which line widths Wa and Wb are different, a phase converter constituted so that two signals leading to the combined signal have an almost equal passage loss can be used for the antenna of the present invention. Similarly, even if the phase converter shown in Fig. 6A has the first and the third lines 23a and 23c with different line widths W1 and W2, and the second and the fourth lines 23b and 23d with different line widths Wa and Wb, a phase converter constituted so that two signals leading to the combined signal have an almost equal passage loss can be used for the antenna of the present invention.

WHAT IS CLAIMED IS:

1. An antenna for transmitting and receiving a radio wave, comprising:

an antenna body for a circularly polarized wave which is formed into a quadrangular flat board constituted from an electric conductor and which outputs reception signals of a different phase respectively from two feeding points; and

a phase converter which converts the two signals of a different phase inputted from the respective feeding points of the antenna body into signals of an equal phase and outputs a combined signal into which the two signals are combined,

wherein the phase converter is formed into a near V-shape corresponding to a shape in the vicinity of a corner portion of the quadrangular antenna body, and is arranged on nearly the same plane as the antenna body so that the inner vertex of the nearly V-shaped portion faces the corner portion of the quadrangular antenna body.

2. The antenna set forth in claim 1, wherein said phase converter and antenna body are formed on the same board so that the inner vertex of the nearly V-shaped portion of the phase converter faces the corner portion of the quadrangular antenna body.

3. The antenna set forth in claim 1 or 2, wherein said phase converter is formed into a near V-shape bent in the middle of the longitudinal length of an electric conductor forming a long circular line,

first and second I/O ports into which said two signals of a different phase are inputted being formed on the inner line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of the radio wave transmitted and received by the antenna,

a third I/O port from which said combined signal is outputted and a fourth I/O port connected to a resistor element having a resistance value equivalent to the input impedance of an external line to which the third I/O port is connected being formed on the outer line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of the radio wave transmitted and received by the antenna,

a line width between the first and the second I/O ports and a line width between the third and the fourth I/O ports being determined so that the two signals inputted to the first and the second I/O ports have an equal passage loss.

4. A phase converter for converting two signals of a different phase inputted from the outside to signals of an equal phase and outputting a combined signal into which the two signals after the phase conversion are combined,

the phase converter being an electric conductor forming a long circular line which is formed into a near V-shape bent in the middle of the longitudinal length,

first and second I/O ports into which the two signals of a different phase are inputted being formed on the inner line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of the signal inputted from the outside,

a third I/O port from which said combined signal is outputted and a fourth I/O port connected to a resistor element having a resistance value equivalent to the input impedance of an external line to which the third I/O port is connected being formed on the outer line of the nearly V-shaped bent portion of the electric conductor in positions symmetric with respect to the bent portion and in positions where the length between the ports is about one fourth of a wavelength λg of the signal inputted from the outside,

a line width between the first and the second I/O ports and a line width between the third and the fourth I/O ports being determined so that the two signals inputted to the first and the

second I/O ports have an equal passage loss.

5. A communication apparatus which transmits and receives data to and from the outside by way of a radio wave, comprising an antenna for transmitting and receiving the radio wave,

wherein the antenna is one of those antennas set forth in claims 1-3.

ANTENNA, PHASE CONVERTER AND COMMUNICATION APPARATUS

ABSTRACT OF THE DISCLOSURE

In an antenna provided in an ERP onboard device, a phase converter is formed into a nearly V-shaped flat board which corresponds to a shape in the vicinity of a corner of a quadrangular antenna body. The phase converter and the antenna body are arranged on the same RF board so that the inner vertex of the nearly V-shaped portion of the phase converter faces the corner of the quadrangular antenna body. The antenna comprising the aforesaid phase converter does not create waste spaces between the phase converter and the antenna body. Therefore, the substantial area occupied by the antenna body and the phase converter can be reduced, and accordingly, miniaturization of the antenna is possible.

Figure 2