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(54) RADIO COMMUNICATION SYSTEM AND APPARATUS

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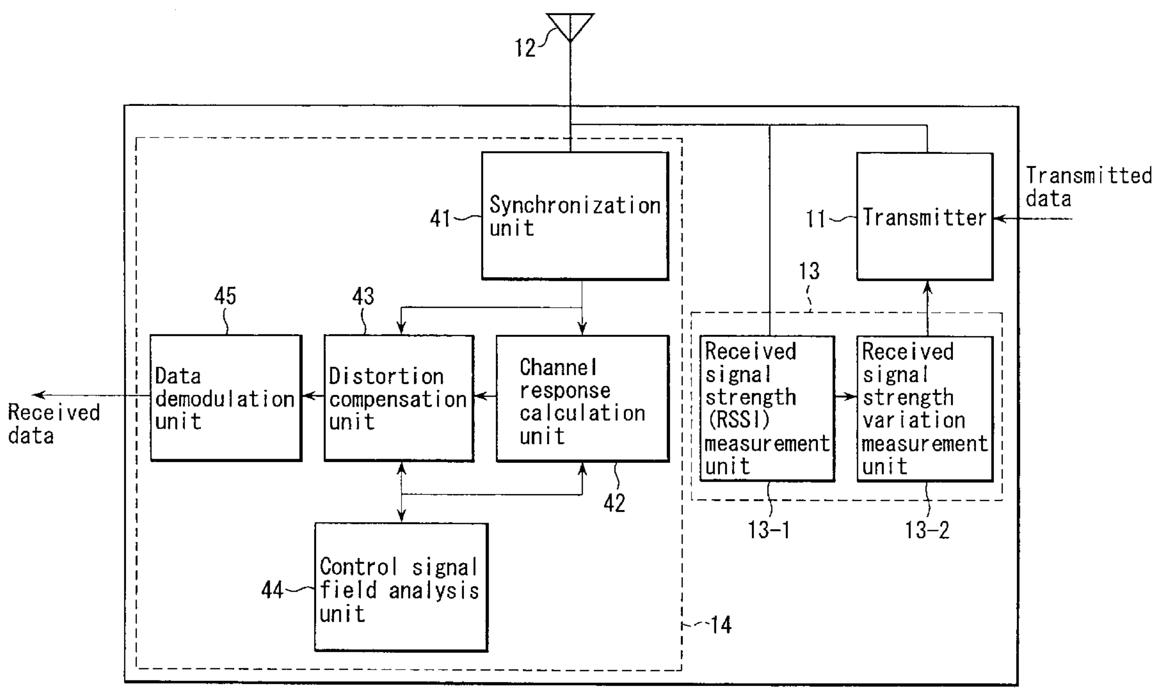
(57) ABSTRACT

A radio communication system for transmitting a radio signal with a transmission format in which a channel response calculation preamble signal serving as a reference upon reception is inserted is disclosed. The output frequency of channel response calculation preamble signals is varied in accordance with a temporal change in radio propagation environment. A channel response variation measurement unit measures a variation of the radio propagation environment. A channel response calculation preamble signal output frequency setting unit sets the output frequency of preamble signals in accordance with the temporal change in radio propagation environment. The preamble signals are inserted in the transmission format to be transmitted at that frequency.



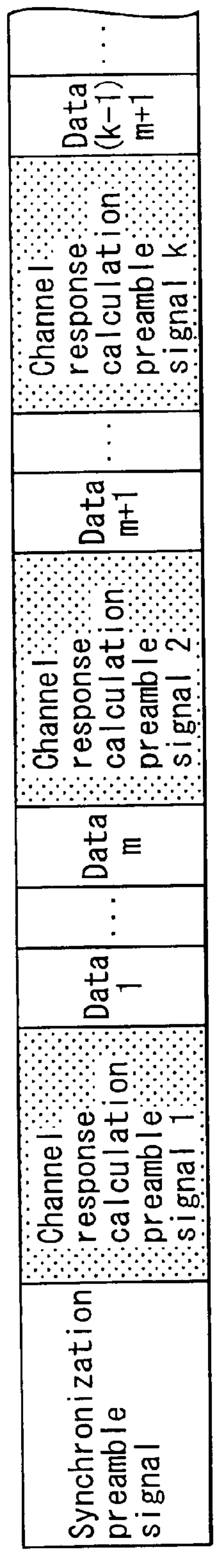

Synchronization preamble signal
Channel response calculation preamble signal 1
Data 1
...
Data m
Channel response calculation preamble signal 2
Data m+1
...
Channel response calculation preamble signal k
Data (k-1) m+1
...

FIG. 1

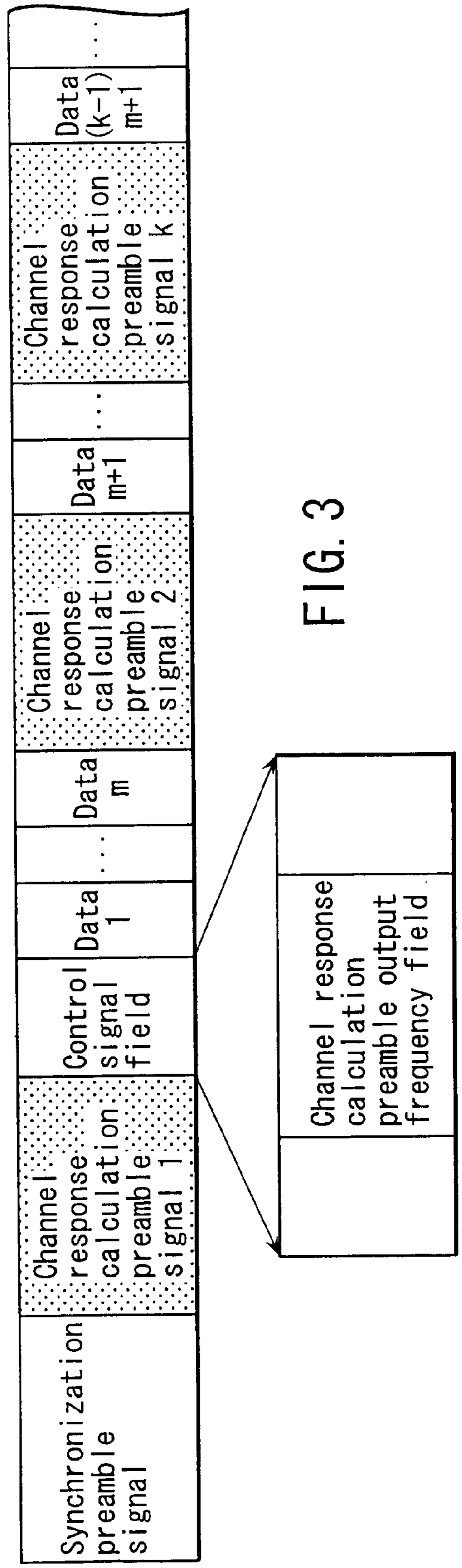

Synchronization preamble signal
Channel response calculation preamble signal 1
Control signal field
Data 1
...
Data m
Channel response calculation preamble signal 2
Data m+1
...
Channel response calculation preamble signal k
Data (k-1) m+1
...
Channel response calculation preamble output frequency field

FIG. 3

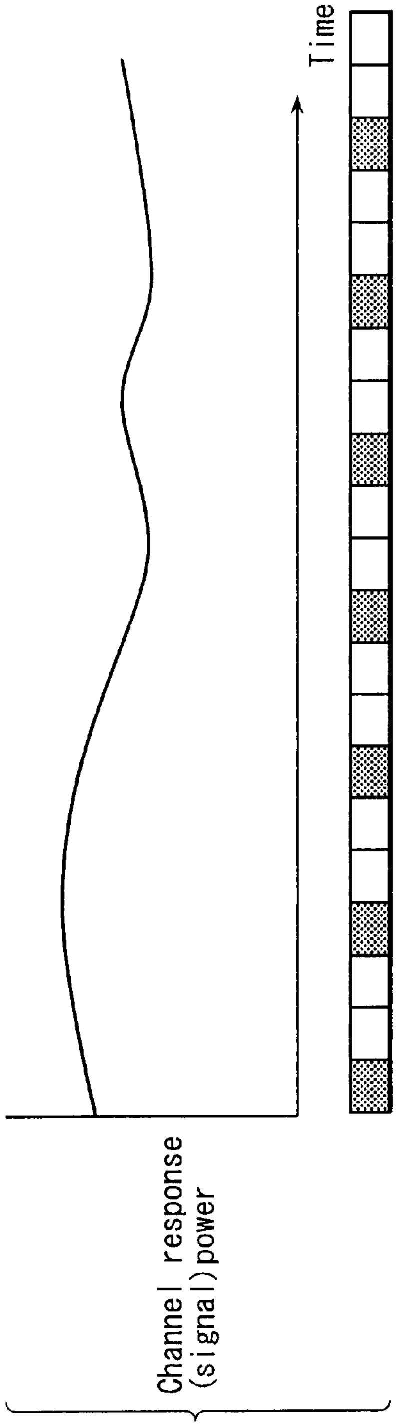

Time
Channel response
(signal) power

FIG. 2A

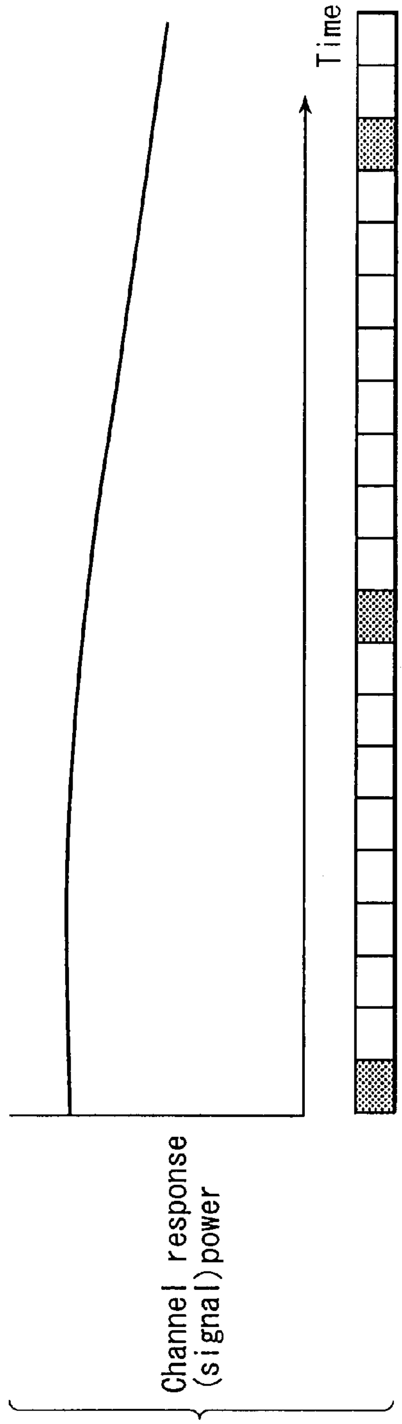

Time
Channel response
(signal) power

FIG. 2B

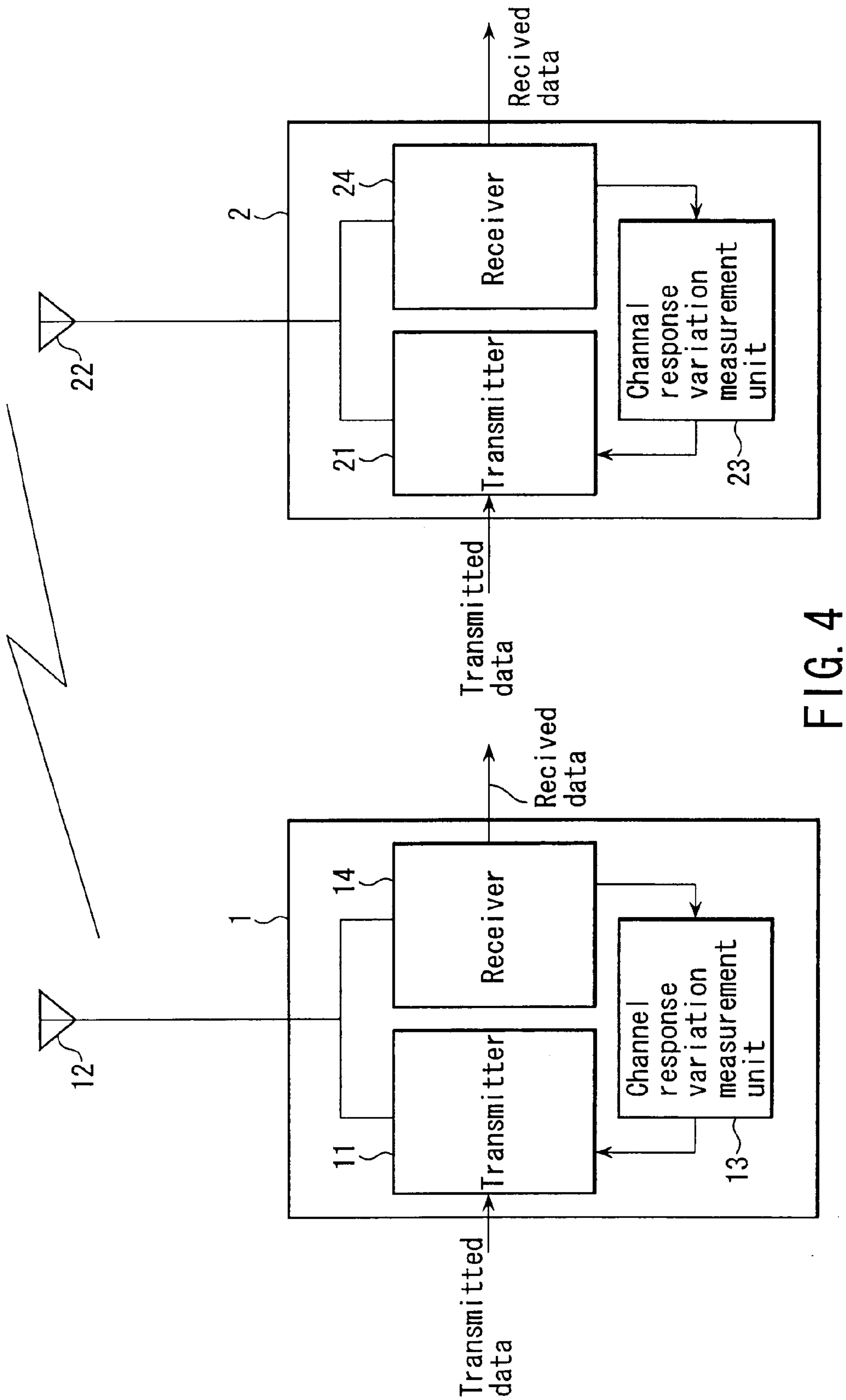

Transmitted data
Transmitter
Receiver
Recived data
Channel response variation measurement unit
1
11
12
13
14
Transmitted data
Transmitter
Receiver
Recived data
Channel response variation measurement unit
2
21
22
23
24

FIG. 4

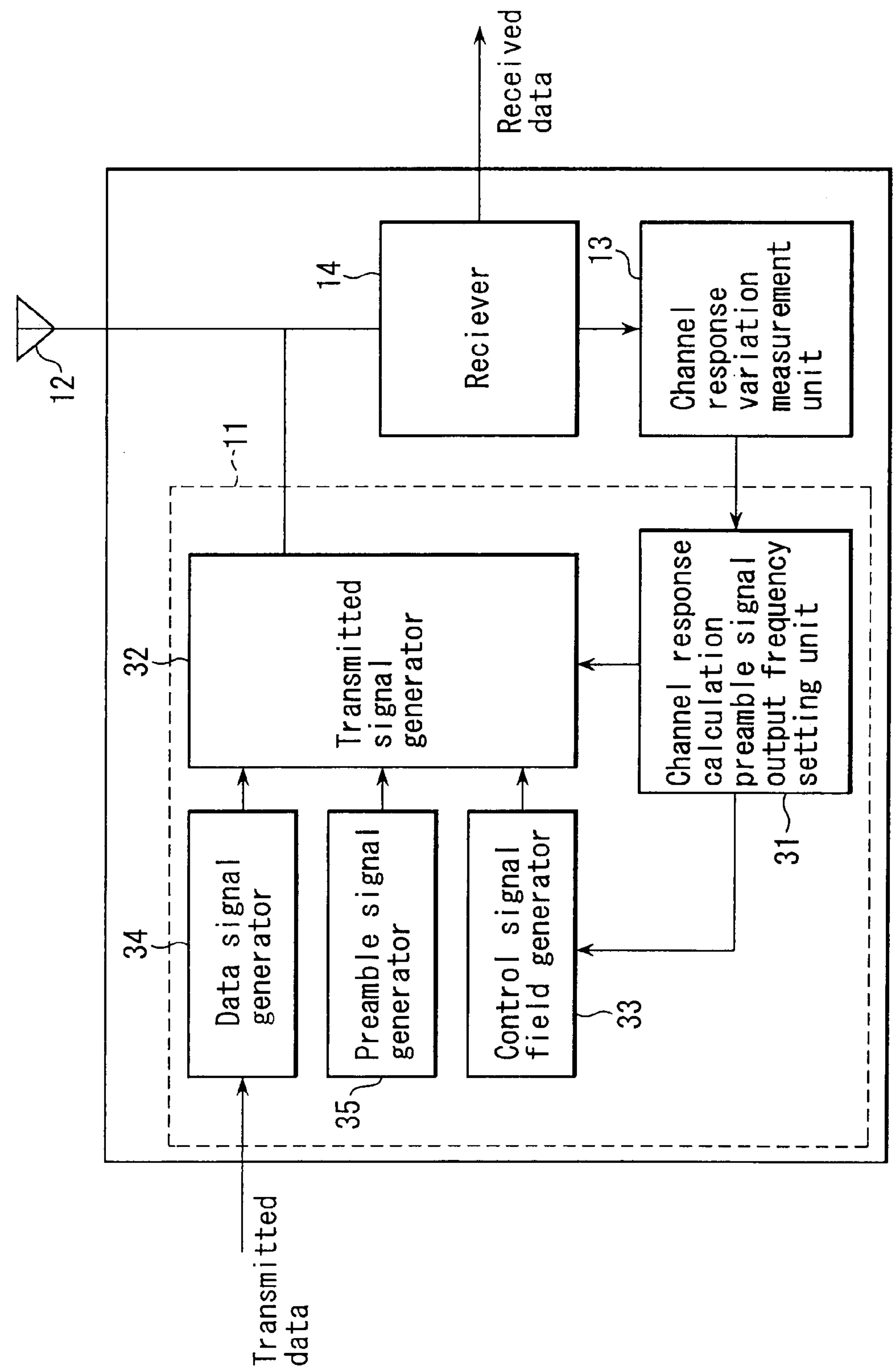

Received data
12
14
Reciever
13
Channel response variation measurement unit
11
32
Transmitted signal generator
Channel response calculation preamble signal output frequency setting unit
31
34
Data signal generator
Preamble signal generator
35
Control signal field generator
33
Transmitted data

FIG. 5

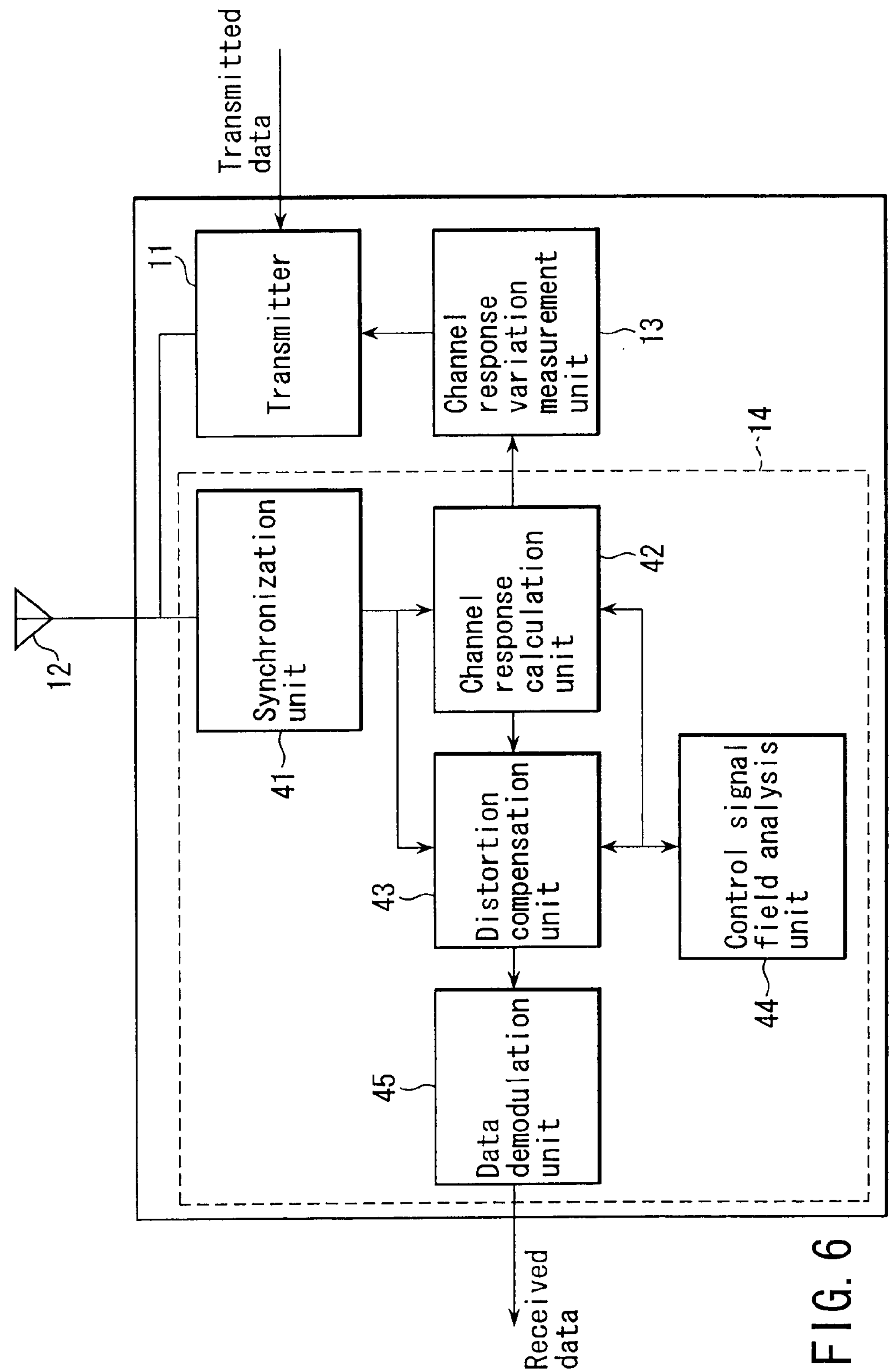

Transmitted data
11
Transmitter
Channel response variation measurement unit
13
14
12
Synchronization unit
41
Channel response calculation unit
42
Distortion compensation unit
43
Control signal field analysis unit
44
Data demodulation unit
45
Received data

FIG. 6

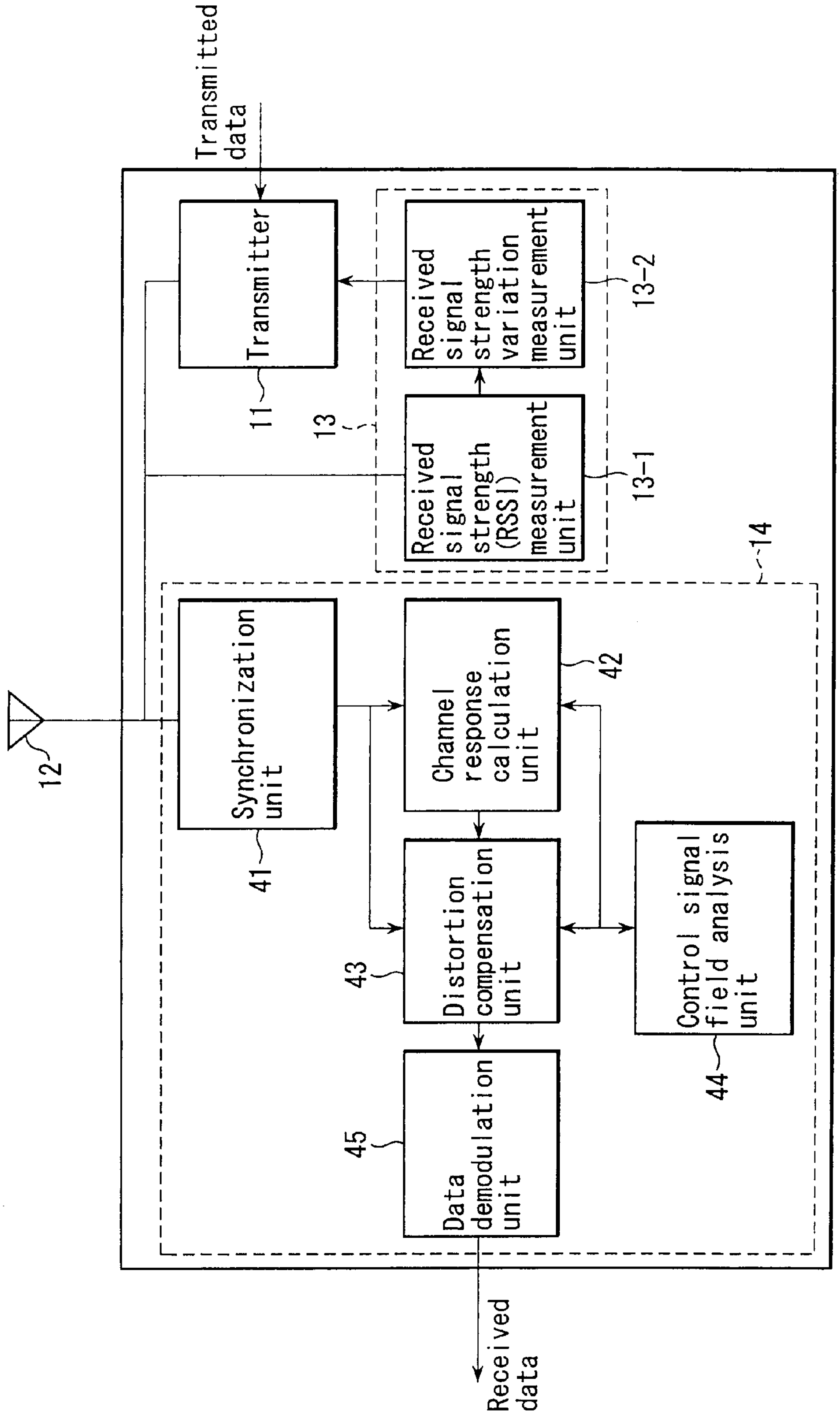

Transmitted data
Transmitter
11
Received signal strength (RSSI) measurement unit
13-1
Received signal strength variation measurement unit
13-2
13
12
Synchronization unit
41
Channel response calculation unit
42
Distortion compensation unit
43
Control signal field analysis unit
44
Data demodulation unit
45
14
Received data

FIG. 7

RADIO COMMUNICATION SYSTEM AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present continuation application claims the benefit of priority under 35 U.S.C. §120 to application Ser. No. 10/102,835, filed on Mar. 22, 2002, and under 35 U.S.C. §119 from Japanese Application No. 2001-087040, filed on Mar. 26, 2001, the entire contents of both are hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a radio communication apparatus, system and method for transmitting a radio signal in accordance with a transmission format in which a channel response calculation preamble signal serving as a reference is inserted.

[0004] 2. Description of the Related Art

[0005] In recent years, a radio data communication system which can make high-speed data communications indoors or outdoors is required. In a radio communication system that implements high-speed data communications, distortions due to multi-pass interference, i.e., reception of a transmitted signal via various routes due to reflection by buildings, and the like, must be compensated for.

[0006] When a transmitter transmits a known reference signal (channel response calculation preamble signal), a receiver calculates the channel response of the channel response calculation preamble signal. The channel response indicates the degree of distortion of phase, amplitude, or the like. The receiver multiplies the received data signal by the inverse characteristic of the channel response to compensate the received data signal for any distortion.

[0007] Conventionally, an insertion method of the channel response calculation preamble signal is fixed in a system. This method includes a method of inserting a channel response calculation preamble signal at given time intervals, a method of inserting at the head of a packet or frame sent toward a given user, and the like.

[0008] When a channel variation is large with respect to a packet length, the channel response calculation result obtained from the channel response calculation preamble signal has a large error from the channel distortion which is actually superposed on the data.

[0009] In order to reduce such error, when the frequency of insertion of the channel response calculation preamble signal is increased, the data transmission efficiency lowers when the channel variation is small.

[0010] As described above, in the conventional radio communication system and radio transmission apparatus, a large error is generated between the channel response calculated from the channel response calculation preamble signal and the channel distortion superposed on data due to a channel variation and, as a result, a reception error rate impairs. In order to reduce the error between the calculated channel response and distortion superposed on data, if the frequency of output of the channel response calculation preamble signal is fixed to be high, the data transmission efficiency lowers when the channel variation is small.

BRIEF SUMMARY OF THE INVENTION

[0011] It is, therefore, an object of the present invention to provide a radio communication apparatus, system and method, which can accurately calculate a channel response and can reduce any transmission error even when the channel variation is large.

[0012] According to one aspect of the present invention, a radio communication method for transmitting a transmitted signal including a preamble signal used for calculating a channel response at a receiving side, comprises setting an output frequency of the preamble signal based on a temporal change of a radio propagation environment; and generating the transmitted signal by inserting the preamble signal in accordance with the output frequency.

[0013] With this method, when the channel variation is large, the frequency of output of the channel response calculation preamble signal can be increased, and distortion correction that traces the channel variation along with an elapse of time can be made. On the other hand, when the channel variation is small, the frequency of output of the channel response calculation preamble signal can be decreased, and the data transmission efficiency can be improved.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0014] FIG. **1** shows an example of the transmitted signal format of a radio communication system according to the present invention;

[0015] FIG. **2**A is a graph showing a temporal variation of (signal) power as a channel response when the variation is large;

[0016] FIG. **2**B is a graph showing a temporal variation of power as a channel response when the variation is small;

[0017] FIG. **3** shows an example of the transmitted signal format of a radio communication system according to the present invention;

[0018] FIG. **4** is a block diagram showing an embodiment of a radio transmission apparatus according to the present invention;

[0019] FIG. **5** is a block diagram showing an embodiment of a radio transmission apparatus according to the present invention;

[0020] FIG. **6** is a block diagram showing an embodiment of a radio transmission apparatus according to the present invention; and

[0021] FIG. **7** is a block diagram showing another embodiment of a radio transmission apparatus according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0022] A radio transmission system and apparatus according to an embodiment of the present invention will be described hereinafter with reference to the accompanying drawings.

[0023] FIG. **1** shows an example of the transmitted signal format of a radio communication system according to the present invention. A transmitted signal is made up of a synchronization preamble signal, at least one channel response calculation preamble signal (k signals in FIG. **1**), and a plurality of data. The number of channel response calculation preamble signals is variable in accordance with a channel variation. The transmitting side controls the frequency of the channel response calculation preamble signal in accordance with the channel variation.

[0024] FIGS. **2**A and **2**B are examples of graphs showing temporal variations of power as a channel response. The abscissa shows time, and the ordinate shows the intra-band average power of the channel response. FIG. **2**A shows a temporal variation of power when the temporal variation of channel response is large, and FIG. **2**B shows a temporal variation of power when the temporal variation of channel response is small.

[0025] An appropriate channel format corresponding to the temporal variation of power of the channel response is shown below each graph that shows the temporal variation of power of the channel response. As shown in FIG. **2**A, when the temporal variation of channel response is large, the frequency of insertion of channel response calculation preamble signal is increased. A channel response to be calculated to compensate for a data distortion can be updated in correspondence with the temporal variation of channel response. Therefore, a transmission error can be reduced. That is, when the temporal variation of channel response is large, a data length m between two channel response calculation preamble signals is set to be a small value, thus reducing transmission errors.

[0026] On the other hand, as shown in FIG. **2**B, when the temporal variation of channel response is small, the frequency of insertion of the channel response calculation preamble signal is decreased, since the channel response need not be calculated frequently. As a result, the ratio of the total length of channel response calculation preamble signals to the total data length decreases. Hence, the data transmission efficiency can be improved.

[0027] In brief, according to the present invention, the number of channel response calculation preamble signals inserted is varied in accordance with the temporal variation of channel response.

[0028] One embodiment of the present invention will be described below. FIG. **3** shows an example of the transmitted signal format in a radio communication system and radio transmission apparatus according to an embodiment of the present invention, and FIGS. **4**, **5**, and **6** are block diagrams.

[0029] In the transmitted signal format shown in FIG. **3**, a control signal field written with control information, which is used to demodulate data, is added to the transmitted signal format shown in FIG. **1**. Since this control signal field is included, the receiving side can normally demodulate data by recognizing control information written in the control signal field.

[0030] In FIG. **3**, the control signal field is inserted immediately after the first channel response calculation preamble signal, but its insertion position is not particularly limited. The control signal field contains a channel response calculation preamble signal output frequency field. The transmitting side writes transmission frequency information of channel response calculation preamble signals in the channel response calculation preamble signal output frequency field. The receiving side can detect the transmission frequency of channel response calculation preamble signals set at the transmitting side with reference to the contents of the channel response calculation preamble signal output frequency field, and can calculate a channel response at a correct timing.

[0031] That is, in the transmitted signal format shown in FIG. **3**, since the synchronization preamble signal and channel response calculation preamble signal are always attached to the head of a packet. If the receiving side can detect the output frequency, it can detect the position of the next channel response calculation preamble signal. The output frequency indicates that channel response calculation preamble signals are inserted every n symbols, for example.

[0032] FIG. **4** shows an example of a radio transmission apparatus according to the present invention. A base station **1** and terminal **2** have radio transmission apparatuses with the same arrangement. A transmitter **11** of the base station **1** transmits a transmitted signal which contains transmitted data and channel response calculation preamble signals in the transmission format shown in FIG. **3** from an antenna **12**. Note that an optimal number of channel response calculation preamble signals is set in accordance with channel variation information output from a channel variation measurement unit **13**.

[0033] The terminal **2** receives the transmitted signal transmitted from the base station **1** by an antenna **22**, and this signal is input to a receiver **24**. The receiver **24** executes a reception process such as transmission distortion compensation and the like of a received signal using channel response calculation preamble signals, and outputs received data. Also, the receiver **24** outputs information used to measure a variation of channel response to a channel response variation measurement unit **23**. As an input signal to the channel response variation measurement unit **23**, a channel response calculation result or the like of the received signal is used. The channel response variation measurement unit **23** measures a variation of channel response, and outputs the measurement result to a transmitter **21**.

[0034] Note that the measurement method of the variation of channel response includes:

[0035] #1. a method of measuring a change in amplitude or phase from that of the previously calculated channel response every time a channel response is calculated, in consideration of a subcarrier (one or a plurality of subcarriers) that includes the calculated channel response;

[0036] #2. a method of measuring the total (or average) power of respective symbols (as well as data), and measuring a change in amplitude (=power) or phase;

[0037] #3. a method of measuring a change in amplitude or phase of a pilot carrier (for estimating a distortion) contained in each symbol; and the like.

[0038] Furthermore, the transmitter **21** executes the same process as the transmission process of the base station **1**, and outputs a transmitted signal to the base station **1** again. In this manner, a signal is transmitted between the base station **1** and terminal **2**.

[0039] FIG. **5** is a block diagram for explaining the transmitter **11** of the radio transmission apparatus shown in FIG. **4**. Since the radio transmission apparatuses of the base station **1** and terminal **2** have the same arrangement, the transmitter **11** of the base station **1** will be explained as an example.

[0040] The signal which is received by the antenna **12** and has the transmission format shown in FIG. **3** is input to a receiver **14**. The receiver **14** executes a reception process of the received signal (to be described later), and outputs information used to measure a variation of channel response to a channel response variation measurement unit **13**. As an input signal to the channel response variation measurement unit **13**, for example, a channel response calculation result or the like is used. The channel response variation measurement unit **13** measures a variation of channel response, and outputs the measurement result to a channel response calculation preamble signal output frequency setting unit **31**.

[0041] The channel response calculation preamble signal output frequency setting unit **31** determines an optimal output frequency of channel response calculation preamble signals using the measurement result of the channel response variation, and informs a transmitted signal generator **32** and control signal field generator **33** of the output frequency of channel response calculation preamble signals.

[0042] The control signal field generator **33** writes information of the channel response calculation preamble signal output frequency in the control signal field.

[0043] Furthermore, transmitted data is converted into a data signal by a data signal generator **34**, and the data signal, a synchronization preamble signal and channel response calculation preamble signals generated by a preamble signal generator **35**, and the control signal field generated by the control signal field generator **33** are input to the transmitted signal generator **32**. The transmitted signal generator **32** generates a transmitted signal based on the transmitted signal format shown in FIG. **3**, and outputs it from the antenna **12**.

[0044] At this time, the channel response calculation preamble signals are inserted at the frequency set by the channel response calculation preamble signal output frequency setting unit **31**. In this manner, the output frequency of channel response calculation preamble signals can be changed in accordance with a variation of channel response.

[0045] FIG. **6** is a block diagram for explaining the receiver **14** of the radio transmission apparatus of the base station **1** shown in FIG. **4**.

[0046] Referring to FIG. **6**, the signal which is received by the antenna **12** and has the transmission format shown in FIG. **3** is input to a synchronization unit **41**. The synchronization unit **41** synchronizes the received signal, and outputs the synchronized received signal to a channel response calculation unit **42** and distortion compensation unit **43**. When a channel response is calculated using a channel response calculation preamble signal, the channel response calculation preamble signal is input to the channel response calculation unit **42**, and other signals are input to the distortion compensation unit **43**.

[0047] The channel response calculated by the channel response calculation unit **42** is input to the distortion compensation unit **43**. The distortion compensation unit **43** compensates the received signal for any distortion using the channel response calculated by the channel response calculation unit **42**. Of the distortion-compensated signal, the control signal field is input to a control signal field analysis unit **44**, which reads out control information required to demodulate, and supplies it to a data demodulation unit **45**. The data demodulation unit **45** demodulates the distortion-compensated signal, and outputs the demodulated signal as received data.

[0048] Furthermore, the control signal field analysis unit **44** reads out information indicating the channel response calculation preamble signal output frequency, and informs the distortion compensation unit **43** and channel response calculation unit **42** of that channel response calculation preamble signal output frequency.

[0049] The channel response calculation unit **42** supplies a channel response calculation preamble signal to the channel variation measurement unit **13**, which measures the variation of channel response. The frequency of channel response calculation preamble signals to be inserted in the transmitted signal format by the transmitter **11** is changed in accordance with the measurement result.

[0050] In the radio transmission system with the above arrangement, since the frequency of channel response calculation preamble signals to be inserted in the signal format to be transmitted is changed in accordance with the channel variation, the channel response can be accurately calculated even when the channel variation is large, and a transmission error can be reduced.

[0051] Since the channel response calculation preamble signal output frequency is sent to the distortion compensation unit **43** and channel response calculation unit **42**, a channel response can be calculated at an accurate timing, and accurate distortion compensation can be made.

[0052] Upon receiving this format, the channel response calculation unit **42** can correctly recognize the reception timing of a channel response calculation preamble signal based on the received channel response calculation preamble signal output frequency information, and can calculate a channel response at a correct timing. Also, the distortion correction unit **43** can correctly recognize the distortion compensation timing of data or the control signal field based on the received channel response calculation preamble signal output frequency. The distortion-compensated data is input to and demodulated by the demodulation unit **45**. In this way, since the receiving side accurately recognizes the channel response calculation preamble signal output frequency, the data and control signal field can undergo distortion correction at correct timings. For this reason, even when the transmitting side varies the channel response calculation preamble signal output frequency, the data signal can be correctly demodulated.

[0053] The transmitted signal format shown in FIG. **3** contains the channel response calculation preamble signal output frequency field used to inform, from the transmitting side, the receiving side of the channel response calculation preamble signal transmission frequency. In place of assuring the control signal field, as shown in FIG. **1**, information indicating the channel response calculation preamble signal output frequency may be contained in data.

[0054] In the above embodiment, the channel response calculation preamble signal output frequency information is written in the transmitted signal. However, in some cases, no channel response calculation preamble signal output frequency information may be written in the transmitted signal. In such case, the control signal field generator **33** of the transmitter, and the control signal analysis unit **44** of the receiver may be omitted.

[0055] When the channel response calculation preamble signal output frequency is not available, a method of calculating a correlation between each symbol and a channel response calculation preamble signal on the receiving side, and determining a symbol with high correlation as a channel response calculation preamble signal may be used.

[0056] As an input signal to the channel response variation measurement unit **13**, received signal strength (RSSI) information of a received signal may be used. Using the RSSI, a variation of channel response is measured. In this case, as shown in FIG. **7**, the channel response variation measurement unit **13** comprises a received signal strength measurement unit **13-1** and received signal strength variation measurement unit **13-2**. The received signal strength measurement unit **13-1** measures the received signal strength of a received signal from the antenna **12**, and the received signal strength variation measurement unit **13-2** measures a variation of received signal strength. Furthermore, the result of the received signal strength variation measurement unit **13-2** is input to the channel response calculation preamble signal output frequency setting unit **31** of the transmitter **11**, thus setting the channel response calculation preamble signal output frequency in correspondence with the channel variation.

[0057] In the embodiment shown in FIG. **5**, the channel response calculation preamble signal output frequency is set inside the transmitter of the radio transmission apparatus that generates a transmitted signal. However, some radio transmission system may receive channel response calculation preamble signal output frequency information from a communication partner. In such case, the channel response variation measurement unit **13** and channel response calculation preamble frequency setting unit **31** may be omitted. Channel response calculation preamble signals may be inserted into the transmission format of a transmitted signal based on the channel response calculation preamble signal transmission frequency provided from the communication partner.

[0058] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit and scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A radio communication apparatus comprising:
a receiver receiving a radio signal;
a first unit configured to obtain a channel response by use of the radio signal;
a second unit configured to measure amplitude or phase from an obtained channel response by the second unit and to determine a variation of a radio propagation environment based on a measured result;
a third unit configured to set a frequency of insertion of preamble signals based on the variation, the preamble signals being used for obtaining a channel response at a receiving side; and
a transmitted signal generator configured to generate a transmitted signal by inserting the preamble signals in accordance with the set frequency of insertion and inserting an output frequency field indicating the frequency of insertion of the preamble signals, the preamble signals being separated with respect to time,
wherein the third unit refers to an output frequency field contained in the radio signal received by the receiver so as to control the frequency of insertion based on the output frequency field.

2. The apparatus according to claim **1**, wherein the frequency of insertion of the preamble signals are increased as the variation of the radio propagation environment gets larger.

3. A radio communication method comprising:
receiving a radio signal;
obtaining a channel response by use of the radio signal;
measuring amplitude or phase from an obtained channel response by the obtaining, and determining a variation of a radio propagation environment based on a measured result;
setting a frequency of insertion of preamble signals based on the variation, the preamble signals being used for obtaining a channel response at a receiving side; and
generating a transmitted signal by inserting the preamble signals in accordance with the set frequency of insertion and inserting an output frequency field indicating the frequency of insertion of the preamble signals, the preamble signals being separated with respect to time,
wherein the third unit refers to an output frequency field contained in the radio signal received by the receiving so as to control the frequency of insertion based on the output frequency field.

4. The method according to claim **3**, wherein the frequency of insertion of the preamble signals are increased as the variation of the radio propagation environment gets larger.

5. A radio communication apparatus comprising:
a receiver receiving a radio signal having symbols;
a first unit configured to calculate a total power of the symbols;
a second unit configured to measure amplitude or phase of the total power, to determine a variation of a radio propagation environment based on a measured result;
a third unit configured to set a frequency of insertion of preamble signals based on the variation, the preamble signals being used for obtaining a channel response at a receiving side; and
a transmitted signal generator configured to generate a transmitted signal by inserting the preamble signals in accordance with the frequency of insertion, the preamble signals being separated with respect to time,
wherein the third unit refers to an output frequency field contained in the radio signal received by the receiver so as to control the frequency of insertion based on the output frequency field.

6. The apparatus according to claim **5**, wherein the frequency of insertion of the preamble signals is increased as the variation of the radio propagation environment gets larger.

7. A radio communication apparatus comprising:
a receiver receiving a radio signal having symbols, the symbols each including a pilot carrier;
a first unit configured to measure amplitude or phase of the pilot carrier, to determine a variation of a radio propagation environment based on a measured result;
a second unit configured to set a frequency of insertion of preamble signals based on the variation, the preamble signals being used for obtaining a channel response at a receiving side; and
a transmitted signal generator configured to generate a transmitted signal by inserting the preamble signals in accordance with the frequency of insertion, the preamble signals being separated with respect to time,
wherein the second unit refers to an output frequency field contained in the radio signal received by the receiver so as to control the frequency of insertion based on the output frequency field.

8. The apparatus according to claim **7**, wherein the frequency of insertion of the preamble signals is increased as the variation of the radio propagation environment gets larger.

* * * * *