

## DESCRIPTION

### COMMUNICATION APPARATUS AND COMMUNICATION SYSTEM

#### Technical Field

5           The present invention relates to a communication apparatus and a communication system that are applied to remote control of an electronic device, for example, by a wireless communication system.

#### 10       Background Art

          When a home electronic device is remotely controlled by a wireless communication system using a 2.4 GHz ISM (Industrial, Scientific and Medical use) band, the influence of obstructions becomes smaller and  
15       the coverage range becomes larger than by an infrared communication system. In addition to such a wireless communication system, this band has been also assigned to microwave heating. Thus, there is a problem that  
20       unnecessary radio waves (hereinafter referred to as interference waves) radiated from a microwave oven that performs microwave heating adversely interfere with the home wireless communication system. In the microwave oven, a magnetron generates microwaves of a 2.4 GHz to 2.5 GHz frequency band. In addition, there are two  
25       magnetron driving types, a transformer type and an inverter type.

          In the transformer type, a commercial power

supply voltage of, for example, 50 Hz is raised by a transformer and the raised voltage is applied to the magnetron. Thus, in one period  $T$  (20 ms) of a sine wave shown in Fig. 1A of the commercial power supply voltage, a non-operative region of a negative half period  $T_1$  (10 ms) occurs as shown in Fig. 1B. For example, in a real microwave oven product, the oscillation frequency of the magnetron is 2.45 GHz and electromagnetic waves periodically occur five times in an operative region (positive half period). In the inverter type, after a power supply voltage is full-wave rectified, the rectified voltage is switched by a switching device, the resultant voltage is raised by a transformer, and then applied to the magnetron. Thus, in the inverter type, until the commercial power supply voltage has been raised up to an operation start voltage of the magnetron, microwaves do not occur and a non-operative region  $T_2$  (1 to 2 ms) occurs as shown in Fig. 1C. In these non-operative regions  $T_1$  and  $T_2$ , since microwaves do not occur, no interference with wireless communication occurs.

A technique of compressing information data and transmitting the compressed information data in the foregoing non-operative region  $T_1$  or  $T_2$  taking into account of the fact that a microwave oven generates interference waves in synchronization with the period of a commercial power supply is described in patent

document, "Japanese Patent Application Laid-Open No.  
HEI 11-112441".

In addition, patent document, "Japanese  
Patent Application Laid-Open No.2002-111603" describes  
5 a technology of which when a non-operative region has  
not been detected from a commercial power supply and an  
interference wave detecting section has detected a good  
environment in which there is no influence of  
interference waves, the frequency is hopped to another  
10 frequency and that when electromagnetic waves that a  
microwave oven had generated have been received as  
interference waves, the frequency of a control signal  
that serves to secure a communication connection state  
is changed to another frequency that the interference  
15 waves do not influence.

In the foregoing methods of the related art,  
since a frequency distribution of interference waves is  
not considered, the influence of interference waves is  
not sufficiently excluded. When the influence of  
20 interference waves to the transmission side is  
different from that to the reception side, their  
influences are not sufficiently reduced. For example,  
in a house, besides a microwave oven, there is another  
interference source such as a wireless LAN.

#### 25 Disclosure of the Invention

Thus, an object of the present invention is

to provide a communication apparatus and a  
communication system that are capable of securely  
suppressing the influence of an interference source  
even if the influence of the interference source to the  
transmission side is different from that to the  
reception side.

To solve the foregoing problem, the present  
invention is a communication apparatus which is  
connected to an electronic device operating with a  
commercial power supply and which bidirectionally  
wirelessly communicates with another communication  
apparatus, the communication apparatus including  
receiving means for receiving data, period detecting  
means for detecting a period of the commercial power  
supply, and transmitting means for transmitting both a  
timing signal which represents the period of the  
commercial power supply detected by the period  
detecting means and acknowledge.

The present invention is a communication  
apparatus which bidirectionally wirelessly communicates  
with another communication apparatus connected to an  
electronic device which operates with a commercial  
power supply, the communication apparatus including  
detecting means for detecting an influence of  
interference waves, receiving means for receiving  
acknowledge from the other communication apparatus, and  
transmitting means for transmitting data and a request

such that the receiving means receives acknowledge for  
the transmitted data at timing of which the influence  
of interference waves is low based on a timing signal  
which represents a period of the commercial power  
5 supply and a detection signal of the detecting means.  
The timing signal which represents a period of the  
commercial power supply is received from the other  
communication apparatus or obtained by the detecting  
means for detecting a period of the commercial power  
10 supply.

The present invention is a communication  
system composed of a first communication apparatus  
connected to an electronic device which operates with a  
commercial power supply and a second communication  
15 apparatus which bidirectionally wirelessly communicates  
with the first communication apparatus, wherein the  
first communication apparatus includes receiving means  
for receiving data from the second communication  
apparatus, period detecting means for detecting a  
20 period of the commercial power supply, and first  
transmitting means for transmitting a timing signal  
which represents a period of the commercial power  
supply detected by the period detecting means and  
acknowledge for the data which have been received, and  
25 wherein the second communication apparatus includes  
detecting means for detecting an influence of  
interference waves, receiving means for receiving the

timing signal which represents the period of the commercial power supply and the acknowledge from the first communication apparatus, and second transmitting means for transmitting data and a request such that the receiving means receives the acknowledge for the transmitted data at timing of which the influence of interference waves is low based on the timing signal and a detection signal of the detecting means.

The first communication apparatus may transmit a beacon signal at the detected period of the commercial power supply.

The present invention is a communication system composed of a first communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which bidirectionally wirelessly communicates with the first communication apparatus, the first communication apparatus and the second communication apparatus communicating with each other through one of a plurality of channels whose frequencies are different, wherein the first communication apparatus includes receiving means for receiving data from the second communication apparatus, detecting means for detecting an influence of interference waves, and transmitting means for transmitting acknowledge for the data which have been received, and wherein the second communication apparatus includes transmitting means for

transmitting a channel acknowledge request to the first communication apparatus through a channel which has been assigned, and channel assigning means for assigning a channel which interference waves do not largely influence detected by the detecting means such that the second transmitting means transmits data through the channel which has been assigned by determining whether or not acknowledge has been received through the channel which has been assigned.

The present invention is a communication system composed of a first communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which bidirectionally wirelessly communicates with the first communication apparatus, the first communication apparatus and the second communication apparatus communicating with each other through one of a plurality of channels whose frequencies are different, wherein the first communication apparatus includes receiving means for receiving data from the second communication apparatus, first detecting means for detecting an influence of interference waves, and transmitting means for transmitting acknowledge for the data which have been received, and wherein the second communication apparatus includes second detecting means for detecting an influence of interference waves, transmitting means for transmitting data to the first

communication apparatus through a channel which  
interference waves do not largely influence detected by  
the first detecting means, and receiving means for  
receiving the acknowledge from the second communication  
5 apparatus through the channel which interference waves  
do not largely influence detected by the second  
detecting means.

According to the present invention, timing of  
the period of the commercial power supply supplied to  
10 an electronic device on the device under control side  
is transmitted, for example, to a remote controlling  
communication apparatus. In addition, the remote  
controlling communication apparatus detects the  
influence of interference waves and transmits data on  
15 the basis of both the received timing and the detected  
influence of interference waves, data can be securely  
transmitted and received regardless of the type of the  
electronic device, the manufacture thereof, and so  
forth. In addition, since the influence of  
20 interference waves is checked for communication  
channels and a communication channel is assigned on the  
basis of the checked result, data can be securely  
transmitted and received through the assigned  
communication channel. Further, when a channel through  
25 which data are transmitted and a channel through which  
acknowledge is received are differently assigned, even  
if the influence of interference waves to the remote

controlling device is different from that to the electronic device, data can be securely transmitted and received therebetween. The present invention can be applied to a remote control system.

5      Brief Description of Drawings

Fig. 1A, Fig. 1B and Fig. 1C are waveform diagrams describing an operative region and a non-operative region of a microwave oven as an interference source;

10      Fig. 2 is a block diagram showing the structure of a transmission side of a communication apparatus according to the present invention;

Fig. 3 is a block diagram showing the structure of a reception side of the communication apparatus according to the present invention;

15      Fig. 4A and Fig. 4B are schematic diagrams describing the influences of interference sources;

Fig. 5A and Fig. 5B are schematic diagrams describing the influences of interference sources;

20      Fig. 6 is a flow chart showing a communication process according to an embodiment of the present invention;

Fig. 7 is a flow chart showing a communication process according to another embodiment of the present invention; and

25      Fig. 8 is a flow chart showing a communication process according to another embodiment

of the present invention.

#### Best Modes for Carrying out the Invention

Next, with reference to the accompanying  
5 drawings, an embodiment of the present invention will  
be described. This embodiment is applied to remotely  
control house electronic device. A communication  
apparatus (commander) that transmits remote control  
data (hereinafter referred to as commands) according to  
10 user's operations is referred to as the remote control  
device. A communication apparatus that receives  
transmitted commands and an electronic device that  
operates according to the received commands are  
generally referred to as the device under control.

15 Examples of the electronic device include AV  
devices such as a video recording/reproducing device,  
an audio recording/reproducing device, and a television  
receiver and home electric appliances such as a  
refrigerator. The remote control device is driven by a  
20 built-in power supply. The device under control is  
driven by a commercial power supply. The device under  
control has a detecting section that detects period  
information of the commercial power supply.

The remote control device and the device  
25 under control each have a transmitter and a receiver  
(that will be described later) such that they can  
wirelessly communicate with each other. As an

exemplary wireless communication system, the physical layer of the IEEE (Institute of Electrical and Electronics Engineers) 802.15.4 standard can be used. The IEEE 802.15.4 standard is a short distance wireless network standard referred to as PAN (Personal Area Network) or W (Wireless) PAN. In this standard, the communication rate is in the range from several 10 kbps to several 100 kbps. In this standard, the communication coverage distance is in the range from several 10 meters to several 100 meters. In this invention, instead of the wireless system, another bidirectional wireless communication standard may be used. However, it is preferred to provide a function of detecting the influence of interference waves to radio channels used for communication.

Fig. 2 shows the structure of a transmitter. Transmission data are supplied to a QPSK (Quadrature Phase Shift Keying) modulator 1 and modulated according to the QPSK modulation method. An output signal of the QPSK modulator 1 is supplied to a spread modulator 2. A spread code generated by a code generator 3 is supplied to the spread modulator 2 and spread according to the DSSS (Direct Sequence Spread Spectrum) method. As an exemplary spread code, a pseudo noise sequence is used. The DS (Direct Spread) method is an SS (Spread Spectrum) method in which a signal is phase-modulated with a high speed spread code and the spectrum of the

signal is spread.

An output signal of the spread modulator 2 is supplied to a multiplier 5 through a band pass filter 4. A local oscillation signal is supplied from a PLL local oscillator 6 to the multiplier 5. The multiplier 5 generates a transmission signal that has been up-converted into a 2.4 GHz frequency band. The transmission signal is supplied to an antenna 8 through an amplifier 7 and then transmitted from the antenna 8.

As communication channels, 16 channels of 2.405 GHz, 2.410 GHz, 2.415 GHz, ..., and 2.480 GHz at intervals of 5 MHz have been assigned. In an embodiment, a plurality of channels, for example, three channels, that are unlikely to overlap with frequencies that are likely to be used in the wireless LAN are used from these 16 channels. Channels are assigned in such a manner that a local oscillation frequency that is output from the local oscillator 6 is selected according to a channel selection signal SL1.

The device under control has a power supply period detecting section 9 and transmits a detected signal that represents timing of the period of the commercial power supply to the remote control device. The remote control device has an input section, for example, keys, switches, buttons, a touch panel, and so forth. The remote control device transmits a command corresponding to an operation of the input section to

the device under control. When the device under control has correctly received the command, the device under control transmits acknowledge ACK as a response signal to the remote control device.

5                    Fig. 3 shows the structure of the receiver.  
A signal received from an antenna 11 is supplied to an LNA (Low Noise Amplifier) 12. The antenna 11 is generally shared by the antenna 8 of the transmitter, and the receiver or the transmitter is selected by a  
10                   transmitter/receiver selection switch. An output signal of the LNA 12 is supplied to a multiplier 13. A local oscillation signal is supplied from a PLL local oscillator 14 to the multiplier 13. The multiplier 13 generates a down-converted IF (Intermediate Frequency)  
15                   signal.

                    The IF signal is supplied to an inverse spread section (spread demodulating section) 16 through an intermediate frequency amplifier 15. The inverse spread section 16 demodulates the IF signal by  
20                   correlating the reception signal with a reference spread code that has occurred on the reception side. Unless timing of the reception signal matches timing of the reference spread code, a correct correlation value cannot be obtained. When starting communication, the  
25                   reception side detects timing and stores the detected timing. To detect timing, a correlating device such as a matched filter is used.

A demodulation signal of the inverse spread section 16 is supplied to a QPSK demodulator 17 and demodulated according to the QPSK demodulation method. Reception data can be obtained from The QPSK demodulator 17. In case of the device under control, the reception data are commands that are used to control an electronic device 20. In case of the remote control device, the reception data are acknowledge ACK that is supplied to a communication control section (not shown).

The demodulation signal of the inverse spread section 16 and the output signal of the LNA 12 are supplied to a CCA (Clear Channel Assessment) section 18. The CCA section 18 determines whether or not an interference power from another system is large based on the received power and the quality of the demodulation signal. In other words, the CCA section 18 determines whether or not interference waves largely influence a channel that is being used. When the determined result denotes that interference waves largely influence the channel that is being used, the CCA section 18 measures interference powers of other channels and determines a channel that interference waves do not largely influence. The IEEE 802.15.4 standard defines functions of CCA and ED (Energy Detection).

The determined result of the CCA section 18

is supplied to a channel selection control section 19. The channel selection control section 19 generates a channel selection signal SL2 based on the determined result. The channel selection signal SL2 controls the local oscillator 14 to select a channel that interference waves do not largely influence. The CCA section 18 of the device under control regularly detects the influence of interference waves. In addition, since the remote control device operates with the built-in power supply, if the CCA section 18 regularly operates, the power consumption of the built-in power supply becomes large. Thus, when necessary, for example, when the remote control device transmits a command to the device under control, the remote control device operates the CCA section 18.

Each of the transmitter and the receiver has a control section (microcomputer) (not shown) for controlling the transmitter or the receiver to perform the transmission or reception operation. The channel selection control section 19 can be accomplished as a function of the control section.

With reference to Fig. 4A, Fig. 4B, Fig. 5A and Fig. 5B, the influences of interference sources such as a microwave oven and a wireless network to frequencies will be described. Fig. 4A shows the case that both a device under control 31 and a remote control device 41 exist in an influence range R of

interference waves of one interference source (for  
example, a microwave oven) 21. In this case, both the  
device under control 31 and the remote control device  
41 are equally influenced by the interference source  
21.

Fig. 4B shows the case that only the device  
under control 31 exists in the influence range R of the  
interference source 21 and that the remote control  
device 41 is outside the influence range R. In this  
case, only the device under control 31 is influenced by  
the interference source 21. When the device under  
control 31 has a detecting section that detects the  
influence of interference waves, the device under  
control 31 assigns a channel that interference waves do  
not largely influence and the remote control device 41  
transmits a command to the device under control 31  
through the assigned channel. The influence of  
interference waves to data that are received is larger  
than that to data that are transmitted. Thus, when a  
command is transmitted through the assigned channel,  
the device under control 31 can receive the command.  
In addition, the remote control device 41 can receive  
acknowledge ACK that the device under control 31 has  
transmitted through the assigned channel.

Fig. 5A shows the case that only the remote  
control device 41 exists in the influence range R of  
the interference source 21 and that the device under

control 31 is outside the influence range R. In this case, only the remote control device 41 is influenced by the interference source 21. In this case, although the device under control 31 can receive a command and the remote control device 41 can transmit a command through a channel that the device under control 31 has assigned, the remote control device 41 is unable to receive acknowledge ACK that the device under control 31 has transmitted.

Further, Fig. 5B shows the case that two interference sources 21 and 22 exist, their influence ranges are R1 and R2, respectively, the device under control 31 exists in the influence range R1, and the remote control device 41 exists in the influence range R2. In this case, the device under control 31 and the remote control device 41 are influenced by the different interference sources. In this case, like the case shown in Fig. 5A, although the remote control device 41 can transmit a command and the device under control 31 can receive a command, the remote control device 41 is unable to receive acknowledge ACK. Thus, in the cases shown in Fig. 5A and Fig. 5B, a problem occurs that even if the device under control 31 assigns a channel that interference waves do not largely influence, communication is not properly performed.

With reference to Fig. 6, an embodiment will be described. The device under control 31 detects

timing of the period of the commercial power supply,  
for example, a zero cross point of a sine wave of the  
power supply. When a 50 Hz commercial power supply is  
used, the device under control 31 detects the zero  
5 cross point at period  $t_1$  of 10 ms. The detection  
process is constantly performed. The period of the  
detected zero cross point is referred to as the period  
information. When the device under control operates in  
synchronization with the commercial power supply, the  
10 period information corresponds to the occurrence period  
of interference waves.

In an embodiment, both the device under  
control 31 and the remote control device 41 have the  
function (CCA) of detecting the influence of  
15 interference waves. In the remote control device 41,  
period  $t_2$  of interference waves at the position where  
the remote control device 41 is provided is measured by  
the function of CCA. Period  $t_2$  is a period at which  
interference waves do not occur. When the remote  
20 control device 41 starts transmitting a predetermined  
command, at step S1, a transmission request for the  
period information is transmitted to the device under  
control 31. The device under control 31 which has  
received the transmission request transmits the period  
25 information (at step S11).

At step S2, the remote control device 41  
which has received the period information determines

whether period  $t_2$  of interference waves matches an integer multiple (for example, twice) of period  $t_1$  of the zero cross point of the commercial power supply. When their differences are in a predetermined tolerance range, the remote control device 41 determines that they match.

When the determined result at step S2 denotes that they match, the remote control device 41 requests the device under control 31 to transmit acknowledge ACK at period  $t_2$  (at step S3). At step S4, a command frame is transmitted. After  $t_2$  has elapsed, at step S5, the remaining command frame is transmitted.

When the device under control 31 has correctly received the command frame from the remote control device 41, the device under control 31 transmits acknowledge ACK to the remote control device 41. In other words, at step S12, the device under control 31 transmits acknowledge ACK to the remote control device 41 in response to the command frame transmitted at step S4 after  $t_2$  has elapsed. At step S13, the device under control 31 transmits acknowledge ACK to the remote control device 41 in response to the command frame transmitted at step S5 after  $t_2$  has elapsed. After the remote control device 41 has received acknowledge ACK, the remote control device 41 completes the transmission.

The number of command frames that the remote

control device 41 transmits is not limited to 2.

Instead, the number of command frames that the remote control device 41 transmits may be 1 or 3 or more.

Whenever the remote control device 41 transmits a

5 sequence of command frames corresponding to operations performed, for example, in several seconds, the foregoing process of preventing the influence of interference waves is performed.

10 When the determined result at step S2 denotes that the period of interference waves is not an integer multiple of  $t_1$ , the remote control device 41 completes the process without transmitting a command frame. In this case, with sound, light, indication, or the like, the remote control device 41 warns the user that the  
15 remote control device 41 has failed to transmit a command frame. When the remote control device 41 has failed to transmit a command frame, the remote control device 41 may retransmit the command frame instead of completing the transmission of the command frame.

20 Instead, the remote control device 41 and the device under control 31 may communicate with each other only in the period of which interference waves do not occur on the basis of both the detected result of the device under control for the period in which  
25 interference waves do not occur at timing in synchronization with the commercial power supply and the detected result of the remote control device for

the period in which the influence of interference waves is not large.

In the foregoing embodiment, since communication is performed using not only period  
5 information of the commercial power supply detected by the device under control side, but information about the influence of interference waves detected by the remote control device, the remote control device and the device under control can properly communicate with  
10 each other. Thus, the remote control device can securely remote-control the device under control. In other words, since the remote control device is isolated from the commercial power supply, the period information of the commercial power supply cannot be  
15 detected. In contrast, although the device under control side can detect interference waves of the wireless system, the device under control can more easily and securely detect interference waves of the commercial power supply than those of the wireless  
20 system. Thus, in an embodiment, to improve the reliability, the remote control device and the device under control transmit and receive a command and acknowledge, respectively, in a region that interference waves do not influence they have  
25 determined. In addition, at the remote control device side, detection of interference waves causes consumption of the power supply. However, remote

control data are transmitted and received in a short period and so are interference waves (8 ms or less for example from an microwave oven). Thus, the power consumption in the case of an embodiment is not larger than that in the case that since detection of interference waves is not performed, a command is failed to be transmitted and received and it is re-transmitted and re-received.

Next, with reference to Fig. 7, another embodiment of the present invention in which a communication channel (frequency) that interference waves do not largely influences is assigned will be described. Fig. 7 shows a channel assignment process of the remote control device. The CCA of the device under control is controlled to detect a channel that interference waves do not largely influence constantly or at intervals of a predetermined period. Thus, a command is received through the detected good channel.

At step S21, the remote control device transmits an acknowledge request for A ch (channel) to the device under control. At step S22, the remote control device determines whether or not it has received acknowledge ACK from the device under control through A ch. For the determination process, a predetermined period is assigned.

When the remote control device has received acknowledge ACK in the predetermined period, the remote

control device determines that A ch is a channel that  
can be currently used. At step S23, A ch is assigned,  
and at step S24, a command frame is transmitted through  
A ch. At step S22, when the remote control device has  
5 determined that it has not received acknowledge ACK  
from the device under control in the predetermined  
period, at step S25, the remote control device  
transmits an acknowledge request for another channel, B  
ch (channel) to the device under control.

10                   At step S26, the remote control device  
determines whether or not it has received acknowledge  
ACK from the device under control through B ch in the  
predetermined period. When the remote control device  
has received acknowledge ACK in the predetermined  
15 period, the remote control device determines that B ch  
is a channel that can be currently used. At step S27,  
B ch is assigned, and at step S28, a command frame is  
transmitted through B ch. At step S26, when the remote  
control device has determined that it has not received  
20 acknowledge ACK in the predetermined period, at step  
S29, a termination process is performed. The  
termination process is a process of repeating the  
channel assignment process, a process of warning the  
user that there is no good communication channel, or  
25 the like. When there are three or more channels that  
the remote control device can select and the determined  
result at step S26 denotes that the remote control

device has not received acknowledge ACK, the remote control device performs the same process for another channel. Whenever the remote control device has transmitted a sequence of command frames corresponding to operations performed, for example, in several seconds, the remote control device performs the process of preventing the influence of interference waves against a communication channel.

The foregoing method of assigning a communication channel is accomplished in combinations with the foregoing method of preventing the influence of interference waves on the time base of the foregoing embodiment. In other words, after a communication channel is assigned according to the foregoing method, a command frame is transmitted according to the method of the foregoing embodiment. However, as shown in Fig. 5A or Fig. 5B, when the remote control device has detected that interference waves do not largely influence a particular channel, the device under control 31 may not have detected so. In this case, the foregoing channel assignment method is insufficient.

With reference to Fig. 8, another embodiment of the present invention where such an insufficient channel assignment method has been improved will be described. First, transmission starts using A ch. A ch is assigned according to the assignment method of the foregoing embodiment. When the remote control

device 41 starts transmitting a command to the device under control, at step S31, the remote control device 41 checks the reception state of A ch that is currently used. In other words, at step S32, the CCA function of the remote control device 41 determines whether or not interference waves largely influence A ch. When the determined result denotes that interference waves do not largely influence A ch, at step S36, a command frame is transmitted.

At step S41, when the device under control 31 has correctly received the command frame through A ch, at step S42, the device under control 31 determines whether or not it has received a transmission request for acknowledge ACK using A ch. When the determined result denotes that the device under control 31 has received the transmission request, at step S44, an acknowledge ACK frame is transmitted to complete transmission and reception of the command frame through A ch.

During processing of the remote control device 41, at step S32, when the remote control device 41 has determined that interference waves largely influence A ch that has been assigned the flow advances to step S33. At step S33, the remote control device 41 checks the reception state of B ch. At step S34, the CCA function of the remote control device 41 determines whether or not interference waves largely influence B

ch. When the determined result at step S34 denotes that interference waves do not largely influence B ch, at step S35, the remote control device 41 transmits a request for acknowledge ACK using B ch to the device under control 31 through A ch. At step S36, a command frame is transmitted through A ch. Since the device under control 31 has assigned A ch as a channel that interference waves do not largely influence, the device under control 31 can receive the request and command frame.

At step S41, when the device under control 31 has received the command frame through A ch, at step S42, the device under control 31 determines whether the remote control device 41 has transmitted a transmission request for acknowledge ACK through A ch. Since the remote control device 41 has transmitted a command frame which request to transmit acknowledge ACK through B ch at step S35, the determined result at step S42 is No.

In this case, at step S43, the device under control 31 assigns B ch as the transmission channel while the device under control 31 has assigned A ch as the reception channel. At step S44, the device under control 31 transmits acknowledge ACK through B ch. Since the remote control device 41 can receive acknowledge ACK, transmission and reception of the command frame is completed.

In the foregoing embodiment of the present invention, whenever the remote control device has transmitted a sequence of command frames corresponding to operations performed, for example, in several  
5 seconds, the remote control device performs the process of preventing the influence of interference waves against a communication channel. In another embodiment, although both the device under control 31 and the remote control device 41 have the detecting  
10 section that detects the influence of interference waves, commands can be more securely transmitted than in the process of transmitting and receiving the detected results of the detecting sections and assigning channels according to the detected results.

15 The present invention is not limited to the foregoing embodiments but various kinds of modifications based on the technical ideas of the invention are possible. For example, the wireless communication method may be based on other than the  
20 IEEE 802.15.4 standard. In addition, the influence of interference waves may be determined according to a bit error rate of reception data.

Furthermore, the device under control may regularly generate a beacon signal at timing of period  
25 information, in particular, a zero cross point of a power supply signal, or a period in which no interference waves occur detected from the power

supply. The remote control device has an internal real time clock, receives a beacon signal, and stores the zero cross point and timing of the period in which no interference waves occur detected from the power

5 supply. When the remote control device has failed to transmit data due to the influence of interference waves, the remote control device generates timing to transmit a command frame based on both timing information that the remote control device has stored  
10 and the period in which no interference waves occur in the power supply. When a predetermined period has elapsed after the remote control device has transmitted a command frame, for example, the power supply of the device under control has been turned on, the remote  
15 control device receives a beacon signal and corrects the internal timing.

Hereinafter, a method of using a beacon signal in the case that interference waves largely influence only a channel that the remote control device  
20 side uses will be exemplified.

1. The remote control device transmits data even in the period in which interference waves occur detected by the remote control device. However, the device under control transmits data, namely the remote  
25 control device receives data in synchronization with the period in which no interference waves occur.

2. The remote control device transmits

## DESCRIPTION

### COMMUNICATION APPARATUS AND COMMUNICATION SYSTEM

#### Technical Field

5           The present invention relates to a communication apparatus and a communication system that are applied to remote control of an electronic device, for example, by a wireless communication system.

#### 10       Background Art

          When a home electronic device is remotely controlled by a wireless communication system using a 2.4 GHz ISM (Industrial, Scientific and Medical use) band, the influence of obstructions becomes smaller and  
15       the coverage range becomes larger than by an infrared communication system. In addition to such a wireless communication system, this band has been also assigned to microwave heating. Thus, there is a problem that  
20       unnecessary radio waves (hereinafter referred to as interference waves) radiated from a microwave oven that performs microwave heating adversely interfere with the home wireless communication system. In the microwave oven, a magnetron generates microwaves of a 2.4 GHz to 2.5 GHz frequency band. In addition, there are two  
25       magnetron driving types, a transformer type and an inverter type.

          In the transformer type, a commercial power

supply voltage of, for example, 50 Hz is raised by a transformer and the raised voltage is applied to the magnetron. Thus, in one period  $T$  (20 ms) of a sine wave shown in Fig. 1A of the commercial power supply voltage, a non-operative region of a negative half period  $T_1$  (10 ms) occurs as shown in Fig. 1B. For example, in a real microwave oven product, the oscillation frequency of the magnetron is 2.45 GHz and electromagnetic waves periodically occur five times in an operative region (positive half period). In the inverter type, after a power supply voltage is full-wave rectified, the rectified voltage is switched by a switching device, the resultant voltage is raised by a transformer, and then applied to the magnetron. Thus, in the inverter type, until the commercial power supply voltage has been raised up to an operation start voltage of the magnetron, microwaves do not occur and a non-operative region  $T_2$  (1 to 2 ms) occurs as shown in Fig. 1C. In these non-operative regions  $T_1$  and  $T_2$ , since microwaves do not occur, no interference with wireless communication occurs.

A technique of compressing information data and transmitting the compressed information data in the foregoing non-operative region  $T_1$  or  $T_2$  taking into account of the fact that a microwave oven generates interference waves in synchronization with the period of a commercial power supply is described in patent

document, "Japanese Patent Application Laid-Open No.  
HEI 11-112441".

In addition, patent document, "Japanese  
Patent Application Laid-Open No.2002-111603" describes  
5 a technology of which when a non-operative region has  
not been detected from a commercial power supply and an  
interference wave detecting section has detected a good  
environment in which there is no influence of  
interference waves, the frequency is hopped to another  
10 frequency and that when electromagnetic waves that a  
microwave oven had generated have been received as  
interference waves, the frequency of a control signal  
that serves to secure a communication connection state  
is changed to another frequency that the interference  
15 waves do not influence.

In the foregoing methods of the related art,  
since a frequency distribution of interference waves is  
not considered, the influence of interference waves is  
not sufficiently excluded. When the influence of  
20 interference waves to the transmission side is  
different from that to the reception side, their  
influences are not sufficiently reduced. For example,  
in a house, besides a microwave oven, there is another  
interference source such as a wireless LAN.

## 25 Disclosure of the Invention

Thus, an object of the present invention is

to provide a communication apparatus and a  
communication system that are capable of securely  
suppressing the influence of an interference source  
even if the influence of the interference source to the  
transmission side is different from that to the  
reception side.

To solve the foregoing problem, the present  
invention is a communication apparatus which is  
connected to an electronic device operating with a  
commercial power supply and which bidirectionally  
wirelessly communicates with another communication  
apparatus, the communication apparatus including  
receiving means for receiving data, period detecting  
means for detecting a period of the commercial power  
supply, and transmitting means for transmitting both a  
timing signal which represents the period of the  
commercial power supply detected by the period  
detecting means and acknowledge.

The present invention is a communication  
apparatus which bidirectionally wirelessly communicates  
with another communication apparatus connected to an  
electronic device which operates with a commercial  
power supply, the communication apparatus including  
detecting means for detecting an influence of  
interference waves, receiving means for receiving  
acknowledge from the other communication apparatus, and  
transmitting means for transmitting data and a request

such that the receiving means receives acknowledge for the transmitted data at timing of which the influence of interference waves is low based on a timing signal which represents a period of the commercial power supply and a detection signal of the detecting means. The timing signal which represents a period of the commercial power supply is received from the other communication apparatus or obtained by the detecting means for detecting a period of the commercial power supply.

The present invention is a communication system composed of a first communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which bidirectionally wirelessly communicates with the first communication apparatus, wherein the first communication apparatus includes receiving means for receiving data from the second communication apparatus, period detecting means for detecting a period of the commercial power supply, and first transmitting means for transmitting a timing signal which represents a period of the commercial power supply detected by the period detecting means and acknowledge for the data which have been received, and wherein the second communication apparatus includes detecting means for detecting an influence of interference waves, receiving means for receiving the

timing signal which represents the period of the commercial power supply and the acknowledge from the first communication apparatus, and second transmitting means for transmitting data and a request such that the receiving means receives the acknowledge for the transmitted data at timing of which the influence of interference waves is low based on the timing signal and a detection signal of the detecting means.

The first communication apparatus may transmit a beacon signal at the detected period of the commercial power supply.

The present invention is a communication system composed of a first communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which bidirectionally wirelessly communicates with the first communication apparatus, the first communication apparatus and the second communication apparatus communicating with each other through one of a plurality of channels whose frequencies are different, wherein the first communication apparatus includes receiving means for receiving data from the second communication apparatus, detecting means for detecting an influence of interference waves, and transmitting means for transmitting acknowledge for the data which have been received, and wherein the second communication apparatus includes transmitting means for

transmitting a channel acknowledge request to the first  
communication apparatus through a channel which has  
been assigned, and channel assigning means for  
assigning a channel which interference waves do not  
5 largely influence detected by the detecting means such  
that the second transmitting means transmits data  
through the channel which has been assigned by  
determining whether or not acknowledge has been  
received through the channel which has been assigned.

10           The present invention is a communication  
system composed of a first communication apparatus  
connected to an electronic device which operates with a  
commercial power supply and a second communication  
apparatus which bidirectionally wirelessly communicates  
15 with the first communication apparatus, the first  
communication apparatus and the second communication  
apparatus communicating with each other through one of  
a plurality of channels whose frequencies are different,  
wherein the first communication apparatus includes  
20 receiving means for receiving data from the second  
communication apparatus, first detecting means for  
detecting an influence of interference waves, and  
transmitting means for transmitting acknowledge for the  
data which have been received, and wherein the second  
25 communication apparatus includes second detecting means  
for detecting an influence of interference waves,  
transmitting means for transmitting data to the first

communication apparatus through a channel which  
interference waves do not largely influence detected by  
the first detecting means, and receiving means for  
receiving the acknowledge from the second communication  
5 apparatus through the channel which interference waves  
do not largely influence detected by the second  
detecting means.

According to the present invention, timing of  
the period of the commercial power supply supplied to  
10 an electronic device on the device under control side  
is transmitted, for example, to a remote controlling  
communication apparatus. In addition, the remote  
controlling communication apparatus detects the  
influence of interference waves and transmits data on  
15 the basis of both the received timing and the detected  
influence of interference waves, data can be securely  
transmitted and received regardless of the type of the  
electronic device, the manufacture thereof, and so  
forth. In addition, since the influence of  
20 interference waves is checked for communication  
channels and a communication channel is assigned on the  
basis of the checked result, data can be securely  
transmitted and received through the assigned  
communication channel. Further, when a channel through  
25 which data are transmitted and a channel through which  
acknowledge is received are differently assigned, even  
if the influence of interference waves to the remote

controlling device is different from that to the electronic device, data can be securely transmitted and received therebetween. The present invention can be applied to a remote control system.

5      Brief Description of Drawings

Fig. 1A, Fig. 1B and Fig. 1C are waveform diagrams describing an operative region and a non-operative region of a microwave oven as an interference source;

10      Fig. 2 is a block diagram showing the structure of a transmission side of a communication apparatus according to the present invention;

Fig. 3 is a block diagram showing the structure of a reception side of the communication apparatus according to the present invention;

15      Fig. 4A and Fig. 4B are schematic diagrams describing the influences of interference sources;

Fig. 5A and Fig. 5B are schematic diagrams describing the influences of interference sources;

20      Fig. 6 is a flow chart showing a communication process according to an embodiment of the present invention;

Fig. 7 is a flow chart showing a communication process according to another embodiment of the present invention; and

25      Fig. 8 is a flow chart showing a communication process according to another embodiment

of the present invention.

#### Best Modes for Carrying out the Invention

Next, with reference to the accompanying  
5 drawings, an embodiment of the present invention will  
be described. This embodiment is applied to remotely  
control house electronic device. A communication  
apparatus (commander) that transmits remote control  
data (hereinafter referred to as commands) according to  
10 user's operations is referred to as the remote control  
device. A communication apparatus that receives  
transmitted commands and an electronic device that  
operates according to the received commands are  
generally referred to as the device under control.

15 Examples of the electronic device include AV  
devices such as a video recording/reproducing device,  
an audio recording/reproducing device, and a television  
receiver and home electric appliances such as a  
refrigerator. The remote control device is driven by a  
20 built-in power supply. The device under control is  
driven by a commercial power supply. The device under  
control has a detecting section that detects period  
information of the commercial power supply.

The remote control device and the device  
25 under control each have a transmitter and a receiver  
(that will be described later) such that they can  
wirelessly communicate with each other. As an

exemplary wireless communication system, the physical layer of the IEEE (Institute of Electrical and Electronics Engineers) 802.15.4 standard can be used. The IEEE 802.15.4 standard is a short distance wireless network standard referred to as PAN (Personal Area Network) or W (Wireless) PAN. In this standard, the communication rate is in the range from several 10 kbps to several 100 kbps. In this standard, the communication coverage distance is in the range from several 10 meters to several 100 meters. In this invention, instead of the wireless system, another bidirectional wireless communication standard may be used. However, it is preferred to provide a function of detecting the influence of interference waves to radio channels used for communication.

Fig. 2 shows the structure of a transmitter. Transmission data are supplied to a QPSK (Quadrature Phase Shift Keying) modulator 1 and modulated according to the QPSK modulation method. An output signal of the QPSK modulator 1 is supplied to a spread modulator 2. A spread code generated by a code generator 3 is supplied to the spread modulator 2 and spread according to the DSSS (Direct Sequence Spread Spectrum) method. As an exemplary spread code, a pseudo noise sequence is used. The DS (Direct Spread) method is an SS (Spread Spectrum) method in which a signal is phase-modulated with a high speed spread code and the spectrum of the

signal is spread.

An output signal of the spread modulator 2 is supplied to a multiplier 5 through a band pass filter 4. A local oscillation signal is supplied from a PLL local oscillator 6 to the multiplier 5. The multiplier 5 generates a transmission signal that has been up-converted into a 2.4 GHz frequency band. The transmission signal is supplied to an antenna 8 through an amplifier 7 and then transmitted from the antenna 8.

As communication channels, 16 channels of 2.405 GHz, 2.410 GHz, 2.415 GHz, ..., and 2.480 GHz at intervals of 5 MHz have been assigned. In an embodiment, a plurality of channels, for example, three channels, that are unlikely to overlap with frequencies that are likely to be used in the wireless LAN are used from these 16 channels. Channels are assigned in such a manner that a local oscillation frequency that is output from the local oscillator 6 is selected according to a channel selection signal SL1.

The device under control has a power supply period detecting section 9 and transmits a detected signal that represents timing of the period of the commercial power supply to the remote control device. The remote control device has an input section, for example, keys, switches, buttons, a touch panel, and so forth. The remote control device transmits a command corresponding to an operation of the input section to

the device under control. When the device under control has correctly received the command, the device under control transmits acknowledge ACK as a response signal to the remote control device.

5                    Fig. 3 shows the structure of the receiver. A signal received from an antenna 11 is supplied to an LNA (Low Noise Amplifier) 12. The antenna 11 is generally shared by the antenna 8 of the transmitter, and the receiver or the transmitter is selected by a  
10                   transmitter/receiver selection switch. An output signal of the LNA 12 is supplied to a multiplier 13. A local oscillation signal is supplied from a PLL local oscillator 14 to the multiplier 13. The multiplier 13 generates a down-converted IF (Intermediate Frequency)  
15                   signal.

                    The IF signal is supplied to an inverse spread section (spread demodulating section) 16 through an intermediate frequency amplifier 15. The inverse spread section 16 demodulates the IF signal by  
20                   correlating the reception signal with a reference spread code that has occurred on the reception side. Unless timing of the reception signal matches timing of the reference spread code, a correct correlation value cannot be obtained. When starting communication, the  
25                   reception side detects timing and stores the detected timing. To detect timing, a correlating device such as a matched filter is used.

A demodulation signal of the inverse spread section 16 is supplied to a QPSK demodulator 17 and demodulated according to the QPSK demodulation method. Reception data can be obtained from The QPSK demodulator 17. In case of the device under control, the reception data are commands that are used to control an electronic device 20. In case of the remote control device, the reception data are acknowledge ACK that is supplied to a communication control section (not shown).

The demodulation signal of the inverse spread section 16 and the output signal of the LNA 12 are supplied to a CCA (Clear Channel Assessment) section 18. The CCA section 18 determines whether or not an interference power from another system is large based on the received power and the quality of the demodulation signal. In other words, the CCA section 18 determines whether or not interference waves largely influence a channel that is being used. When the determined result denotes that interference waves largely influence the channel that is being used, the CCA section 18 measures interference powers of other channels and determines a channel that interference waves do not largely influence. The IEEE 802.15.4 standard defines functions of CCA and ED (Energy Detection).

The determined result of the CCA section 18

is supplied to a channel selection control section 19. The channel selection control section 19 generates a channel selection signal SL2 based on the determined result. The channel selection signal SL2 controls the  
5 local oscillator 14 to select a channel that interference waves do not largely influence. The CCA section 18 of the device under control regularly detects the influence of interference waves. In addition, since the remote control device operates with  
10 the built-in power supply, if the CCA section 18 regularly operates, the power consumption of the built-in power supply becomes large. Thus, when necessary, for example, when the remote control device transmits a command to the device under control, the remote control  
15 device operates the CCA section 18.

Each of the transmitter and the receiver has a control section (microcomputer) (not shown) for controlling the transmitter or the receiver to perform the transmission or reception operation. The channel  
20 selection control section 19 can be accomplished as a function of the control section.

With reference to Fig. 4A, Fig. 4B, Fig. 5A and Fig. 5B, the influences of interference sources such as a microwave oven and a wireless network to  
25 frequencies will be described. Fig. 4A shows the case that both a device under control 31 and a remote control device 41 exist in an influence range R of

interference waves of one interference source (for example, a microwave oven) 21. In this case, both the device under control 31 and the remote control device 41 are equally influenced by the interference source 21.

Fig. 4B shows the case that only the device under control 31 exists in the influence range R of the interference source 21 and that the remote control device 41 is outside the influence range R. In this case, only the device under control 31 is influenced by the interference source 21. When the device under control 31 has a detecting section that detects the influence of interference waves, the device under control 31 assigns a channel that interference waves do not largely influence and the remote control device 41 transmits a command to the device under control 31 through the assigned channel. The influence of interference waves to data that are received is larger than that to data that are transmitted. Thus, when a command is transmitted through the assigned channel, the device under control 31 can receive the command. In addition, the remote control device 41 can receive acknowledge ACK that the device under control 31 has transmitted through the assigned channel.

Fig. 5A shows the case that only the remote control device 41 exists in the influence range R of the interference source 21 and that the device under

control 31 is outside the influence range R. In this case, only the remote control device 41 is influenced by the interference source 21. In this case, although the device under control 31 can receive a command and the remote control device 41 can transmit a command through a channel that the device under control 31 has assigned, the remote control device 41 is unable to receive acknowledge ACK that the device under control 31 has transmitted.

Further, Fig. 5B shows the case that two interference sources 21 and 22 exist, their influence ranges are R1 and R2, respectively, the device under control 31 exists in the influence range R1, and the remote control device 41 exists in the influence range R2. In this case, the device under control 31 and the remote control device 41 are influenced by the different interference sources. In this case, like the case shown in Fig. 5A, although the remote control device 41 can transmit a command and the device under control 31 can receive a command, the remote control device 41 is unable to receive acknowledge ACK. Thus, in the cases shown in Fig. 5A and Fig. 5B, a problem occurs that even if the device under control 31 assigns a channel that interference waves do not largely influence, communication is not properly performed.

With reference to Fig. 6, an embodiment will be described. The device under control 31 detects

timing of the period of the commercial power supply,  
for example, a zero cross point of a sine wave of the  
power supply. When a 50 Hz commercial power supply is  
used, the device under control 31 detects the zero  
5 cross point at period  $t_1$  of 10 ms. The detection  
process is constantly performed. The period of the  
detected zero cross point is referred to as the period  
information. When the device under control operates in  
synchronization with the commercial power supply, the  
10 period information corresponds to the occurrence period  
of interference waves.

In an embodiment, both the device under  
control 31 and the remote control device 41 have the  
function (CCA) of detecting the influence of  
15 interference waves. In the remote control device 41,  
period  $t_2$  of interference waves at the position where  
the remote control device 41 is provided is measured by  
the function of CCA. Period  $t_2$  is a period at which  
interference waves do not occur. When the remote  
20 control device 41 starts transmitting a predetermined  
command, at step S1, a transmission request for the  
period information is transmitted to the device under  
control 31. The device under control 31 which has  
received the transmission request transmits the period  
25 information (at step S11).

At step S2, the remote control device 41  
which has received the period information determines

whether period  $t_2$  of interference waves matches an integer multiple (for example, twice) of period  $t_1$  of the zero cross point of the commercial power supply. When their differences are in a predetermined tolerance range, the remote control device 41 determines that they match.

When the determined result at step S2 denotes that they match, the remote control device 41 requests the device under control 31 to transmit acknowledge ACK at period  $t_2$  (at step S3). At step S4, a command frame is transmitted. After  $t_2$  has elapsed, at step S5, the remaining command frame is transmitted.

When the device under control 31 has correctly received the command frame from the remote control device 41, the device under control 31 transmits acknowledge ACK to the remote control device 41. In other words, at step S12, the device under control 31 transmits acknowledge ACK to the remote control device 41 in response to the command frame transmitted at step S4 after  $t_2$  has elapsed. At step S13, the device under control 31 transmits acknowledge ACK to the remote control device 41 in response to the command frame transmitted at step S5 after  $t_2$  has elapsed. After the remote control device 41 has received acknowledge ACK, the remote control device 41 completes the transmission.

The number of command frames that the remote

control device 41 transmits is not limited to 2.

Instead, the number of command frames that the remote control device 41 transmits may be 1 or 3 or more.

Whenever the remote control device 41 transmits a

5 sequence of command frames corresponding to operations performed, for example, in several seconds, the foregoing process of preventing the influence of interference waves is performed.

10 When the determined result at step S2 denotes that the period of interference waves is not an integer multiple of  $t_1$ , the remote control device 41 completes the process without transmitting a command frame. In this case, with sound, light, indication, or the like, the remote control device 41 warns the user that the  
15 remote control device 41 has failed to transmit a command frame. When the remote control device 41 has failed to transmit a command frame, the remote control device 41 may retransmit the command frame instead of completing the transmission of the command frame.

20 Instead, the remote control device 41 and the device under control 31 may communicate with each other only in the period of which interference waves do not occur on the basis of both the detected result of the device under control for the period in which  
25 interference waves do not occur at timing in synchronization with the commercial power supply and the detected result of the remote control device for

the period in which the influence of interference waves is not large.

In the foregoing embodiment, since communication is performed using not only period  
5 information of the commercial power supply detected by the device under control side, but information about the influence of interference waves detected by the remote control device, the remote control device and the device under control can properly communicate with  
10 each other. Thus, the remote control device can securely remote-control the device under control. In other words, since the remote control device is isolated from the commercial power supply, the period information of the commercial power supply cannot be  
15 detected. In contrast, although the device under control side can detect interference waves of the wireless system, the device under control can more easily and securely detect interference waves of the commercial power supply than those of the wireless  
20 system. Thus, in an embodiment, to improve the reliability, the remote control device and the device under control transmit and receive a command and acknowledge, respectively, in a region that interference waves do not influence they have  
25 determined. In addition, at the remote control device side, detection of interference waves causes consumption of the power supply. However, remote

control data are transmitted and received in a short period and so are interference waves (8 ms or less for example from an microwave oven). Thus, the power consumption in the case of an embodiment is not larger than that in the case that since detection of interference waves is not performed, a command is failed to be transmitted and received and it is re-transmitted and re-received.

Next, with reference to Fig. 7, another embodiment of the present invention in which a communication channel (frequency) that interference waves do not largely influences is assigned will be described. Fig. 7 shows a channel assignment process of the remote control device. The CCA of the device under control is controlled to detect a channel that interference waves do not largely influence constantly or at intervals of a predetermined period. Thus, a command is received through the detected good channel.

At step S21, the remote control device transmits an acknowledge request for A ch (channel) to the device under control. At step S22, the remote control device determines whether or not it has received acknowledge ACK from the device under control through A ch. For the determination process, a predetermined period is assigned.

When the remote control device has received acknowledge ACK in the predetermined period, the remote

control device determines that A ch is a channel that  
can be currently used. At step S23, A ch is assigned,  
and at step S24, a command frame is transmitted through  
A ch. At step S22, when the remote control device has  
5 determined that it has not received acknowledge ACK  
from the device under control in the predetermined  
period, at step S25, the remote control device  
transmits an acknowledge request for another channel, B  
ch (channel) to the device under control.

10               At step S26, the remote control device  
determines whether or not it has received acknowledge  
ACK from the device under control through B ch in the  
predetermined period. When the remote control device  
has received acknowledge ACK in the predetermined  
15 period, the remote control device determines that B ch  
is a channel that can be currently used. At step S27,  
B ch is assigned, and at step S28, a command frame is  
transmitted through B ch. At step S26, when the remote  
control device has determined that it has not received  
20 acknowledge ACK in the predetermined period, at step  
S29, a termination process is performed. The  
termination process is a process of repeating the  
channel assignment process, a process of warning the  
user that there is no good communication channel, or  
25 the like. When there are three or more channels that  
the remote control device can select and the determined  
result at step S26 denotes that the remote control

device has not received acknowledge ACK, the remote control device performs the same process for another channel. Whenever the remote control device has transmitted a sequence of command frames corresponding to operations performed, for example, in several seconds, the remote control device performs the process of preventing the influence of interference waves against a communication channel.

The foregoing method of assigning a communication channel is accomplished in combinations with the foregoing method of preventing the influence of interference waves on the time base of the foregoing embodiment. In other words, after a communication channel is assigned according to the foregoing method, a command frame is transmitted according to the method of the foregoing embodiment. However, as shown in Fig. 5A or Fig. 5B, when the remote control device has detected that interference waves do not largely influence a particular channel, the device under control 31 may not have detected so. In this case, the foregoing channel assignment method is insufficient.

With reference to Fig. 8, another embodiment of the present invention where such an insufficient channel assignment method has been improved will be described. First, transmission starts using A ch. A ch is assigned according to the assignment method of the foregoing embodiment. When the remote control

device 41 starts transmitting a command to the device under control, at step S31, the remote control device 41 checks the reception state of A ch that is currently used. In other words, at step S32, the CCA function of the remote control device 41 determines whether or not interference waves largely influence A ch. When the determined result denotes that interference waves do not largely influence A ch, at step S36, a command frame is transmitted.

At step S41, when the device under control 31 has correctly received the command frame through A ch, at step S42, the device under control 31 determines whether or not it has received a transmission request for acknowledge ACK using A ch. When the determined result denotes that the device under control 31 has received the transmission request, at step S44, an acknowledge ACK frame is transmitted to complete transmission and reception of the command frame through A ch.

During processing of the remote control device 41, at step S32, when the remote control device 41 has determined that interference waves largely influence A ch that has been assigned the flow advances to step S33. At step S33, the remote control device 41 checks the reception state of B ch. At step S34, the CCA function of the remote control device 41 determines whether or not interference waves largely influence B

ch. When the determined result at step S34 denotes that interference waves do not largely influence B ch, at step S35, the remote control device 41 transmits a request for acknowledge ACK using B ch to the device under control 31 through A ch. At step S36, a command frame is transmitted through A ch. Since the device under control 31 has assigned A ch as a channel that interference waves do not largely influence, the device under control 31 can receive the request and command frame.

At step S41, when the device under control 31 has received the command frame through A ch, at step S42, the device under control 31 determines whether the remote control device 41 has transmitted a transmission request for acknowledge ACK through A ch. Since the remote control device 41 has transmitted a command frame which request to transmit acknowledge ACK through B ch at step S35, the determined result at step S42 is No.

In this case, at step S43, the device under control 31 assigns B ch as the transmission channel while the device under control 31 has assigned A ch as the reception channel. At step S44, the device under control 31 transmits acknowledge ACK through B ch. Since the remote control device 41 can receive acknowledge ACK, transmission and reception of the command frame is completed.

In the foregoing embodiment of the present invention, whenever the remote control device has transmitted a sequence of command frames corresponding to operations performed, for example, in several  
5 seconds, the remote control device performs the process of preventing the influence of interference waves against a communication channel. In another embodiment, although both the device under control 31 and the remote control device 41 have the detecting  
10 section that detects the influence of interference waves, commands can be more securely transmitted than in the process of transmitting and receiving the detected results of the detecting sections and assigning channels according to the detected results.

15 The present invention is not limited to the foregoing embodiments but various kinds of modifications based on the technical ideas of the invention are possible. For example, the wireless communication method may be based on other than the  
20 IEEE 802.15.4 standard. In addition, the influence of interference waves may be determined according to a bit error rate of reception data.

Furthermore, the device under control may regularly generate a beacon signal at timing of period  
25 information, in particular, a zero cross point of a power supply signal, or a period in which no interference waves occur detected from the power

supply. The remote control device has an internal real time clock, receives a beacon signal, and stores the zero cross point and timing of the period in which no interference waves occur detected from the power supply. When the remote control device has failed to transmit data due to the influence of interference waves, the remote control device generates timing to transmit a command frame based on both timing information that the remote control device has stored and the period in which no interference waves occur in the power supply. When a predetermined period has elapsed after the remote control device has transmitted a command frame, for example, the power supply of the device under control has been turned on, the remote control device receives a beacon signal and corrects the internal timing.

Hereinafter, a method of using a beacon signal in the case that interference waves largely influence only a channel that the remote control device side uses will be exemplified.

1. The remote control device transmits data even in the period in which interference waves occur detected by the remote control device. However, the device under control transmits data, namely the remote control device receives data in synchronization with the period in which no interference waves occur.

2. The remote control device transmits

information that denotes that no interference waves occur and information that represents timing in which they occur. The device under control continuously transmits data when no interference waves occur taking into account of deviation between the information that the device under control has received from the remote control device and the information that the device under control has detected.

3. When interference waves influence a channel that the remote control device uses, it checks whether or not interference waves influence another channel. When there is a channel that interference waves do not influence, the remote control device requests the device under control to transmit data through the channel that interference waves do not influence.

4. The remote control device has a means that measures an elapsed period after the remote control device has transmitted a data transmission command. Until an assigned period has elapsed, the foregoing bidirectional communication means of the remote control device tries to transmit and receive data. When the communication means has failed to communicate with the device under control, the communication means transmits data that does not require acknowledge to the device under control and completes the communication with the device under control.

In the processes 1, 2, and 3, interference

waves influence only the remote control device side.

Of course, interference waves may influence only the device under control. The remote control device side may have a function of detecting period information of the commercial power supply. In this case, it is not necessary to receive period information of the commercial power supply from the electronic device side. Only the remote control device can generate proper timing. To allow the remote control device side to detect the period of the commercial power supply, a photo-electrical converter such as a photo detector that detects for example light of a fluorescent lamp may be disposed in the remote control device.

## CLAIMS

1. A communication apparatus which is connected to an electronic device operating with a commercial power supply and which bidirectionally wirelessly communicates with another communication apparatus, the communication apparatus, comprising:

receiving means for receiving data;

period detecting means for detecting a period of the commercial power supply; and

transmitting means for transmitting both a timing signal which represents the period of the commercial power supply detected by the period detecting means and acknowledge.

2. The communication apparatus as set forth in claim 1,

wherein the receiving means receives remote control data with which the electronic device is controlled.

3. A communication apparatus which bidirectionally wirelessly communicates with another communication apparatus connected to an electronic device which operates with a commercial power supply, the communication apparatus comprising:

detecting means for detecting an influence of interference waves;

receiving means for receiving acknowledge from the other communication apparatus; and

transmitting means for transmitting data and  
a request such that the receiving means receives  
acknowledge for the transmitted data at timing of which  
the influence of interference waves is low based on a  
5 timing signal which represents a period of the  
commercial power supply and a detection signal of the  
detecting means.

4. The communication apparatus as set forth in  
claim 3,

10 wherein the receiving means receives the  
timing signal which represents the period of the  
commercial power supply from the other communication  
apparatus.

5. The communication apparatus as set forth in  
15 claim 3, further comprising:

a detecting device which detects the timing  
signal which represents the period of the commercial  
power supply.

6. The communication apparatus as set forth in  
20 claim 3, further comprising:

an input section,

wherein the transmitting means transmits  
remote control data with which the electronic device is  
remotely controlled, the remote control data  
25 corresponding to a command which is input from the  
input section.

7. A communication system composed of a first

communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which bidirectionally wirelessly communicates with the first communication apparatus,

wherein the first communication apparatus comprises:

receiving means for receiving data from the second communication apparatus;

period detecting means for detecting a period of the commercial power supply; and

transmitting means for transmitting a timing signal which represents a period of the commercial power supply detected by the period detecting means and acknowledge for the data which have been received, and

wherein the second communication apparatus comprises:

detecting means for detecting an influence of interference waves;

receiving means for receiving the timing signal which represents the period of the commercial power supply and the acknowledge from the first communication apparatus; and

transmitting means for transmitting data and a request such that the receiving means receives the acknowledge for the transmitted data at timing of which the influence of interference waves is low based on the

timing signal and a detection signal of the detecting means.

8. The communication system as set forth in claim 7,

5 wherein the first communication apparatus receives remote control data with which the electronic device is remotely controlled.

9. The communication system as set forth in claim 7,

10 wherein the second communication apparatus further comprises an input section which inputs a command with which the electronic device is remotely controlled, and

15 wherein the transmitting means transmits remote control data corresponding to the command which has been input from the input section.

10. A communication system composed of a first communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which  
20 bidirectionally wirelessly communicates with the first communication apparatus,

wherein the first communication apparatus comprises:

25 receiving means for receiving data from the second communication apparatus;

period detecting means for detecting a period

of the commercial power supply; and

transmitting means for transmitting a beacon  
signal at timing corresponding to a period of the  
commercial power supply detected by the period

5 detecting means and acknowledge for the data which have  
been received, and

wherein the second communication apparatus  
comprises:

10 detecting means for detecting an influence of  
interference waves;

receiving means for receiving the beacon  
signal and the acknowledge from the first communication  
apparatus;

15 time information storing means for storing  
time information corresponding to the received beacon  
signal; and

transmitting means for transmitting data and  
a request such that the receiving means receives the  
acknowledge for the transmitted data at timing of which  
20 the influence of interference waves is low based on the  
time information which has been stored and a detection  
signal of the detecting means.

11. The communication system as set forth in  
claim 10,

25 wherein the first communication apparatus  
receives remote control data with which the electronic  
device is remotely controlled.

12. The communication system as set forth in  
claim 10,

wherein the second communication apparatus  
further comprises an input section which inputs a  
5 command with which the electronic device is remotely  
controlled, and

wherein the transmitting means transmits  
remote control data corresponding to the command which  
has been input from the input section.

10 13. A communication system composed of a first  
communication apparatus connected to an electronic  
device which operates with a commercial power supply  
and a second communication apparatus which  
bidirectionally wirelessly communicates with the first  
15 communication apparatus, the first communication  
apparatus and the second communication apparatus  
communicating with each other through one of a  
plurality of channels whose frequencies are different,

wherein the first communication apparatus  
20 comprises:

receiving means for receiving data from the  
second communication apparatus;

detecting means for detecting an influence of  
interference waves; and

25 transmitting means for transmitting  
acknowledge for the data which have been received, and

wherein the second communication apparatus

comprises:

transmitting means for transmitting a channel  
acknowledge request to the first communication  
apparatus through a channel which has been assigned;  
5 and

channel assigning means for assigning a  
channel which interference waves do not largely  
influence detected by the detecting means such that the  
second transmitting means transmits data through the  
10 channel which has been assigned by determining whether  
or not acknowledge has been received through the  
channel which has been assigned.

14. The communication system as set forth in  
claim 13,

15 wherein the first communication apparatus  
receives remote control data with which the electronic  
device is remotely controlled.

15. The communication system as set forth in  
claim 13,

20 wherein the second communication apparatus  
further comprises an input section which inputs a  
command with which the electronic device is remotely  
controlled, and

wherein the transmitting means transmits  
25 remote control data corresponding to the command which  
has been input from the input section.

16. A communication system composed of a first

communication apparatus connected to an electronic device which operates with a commercial power supply and a second communication apparatus which bidirectionally wirelessly communicates with the first communication apparatus, the first communication apparatus and the second communication apparatus communicating with each other through one of a plurality of channels whose frequencies are different,

wherein the first communication apparatus comprises:

receiving means for receiving data from the second communication apparatus;

first detecting means for detecting an influence of interference waves; and

transmitting means for transmitting acknowledge for the data which have been received, and

wherein the second communication apparatus comprises:

second detecting means for detecting an influence of interference waves;

transmitting means for transmitting data to the first communication apparatus through a channel which interference waves do not largely influence detected by the first detecting means; and

receiving means for receiving the acknowledge from the second communication apparatus through the channel which interference waves do not largely

influence detected by the second detecting means.

17. The communication system as set forth in claim 16,

5 wherein the first communication apparatus receives remote control data with which the electronic device is remotely controlled.

18. The communication system as set forth in claim 16,

10 wherein the second communication apparatus further comprises an input section which inputs a command with which the electronic device is remotely controlled, and

15 wherein the transmitting means transmits remote control data corresponding to the command which has been input from the input section.

19. The communication system as set forth in claim 16,

20 wherein when the second detecting means has detected which interference wave largely influence a channel through which the data are transmitted, the first communication apparatus requests the second communication apparatus to communicate through another channel which interference waves do not largely influence detected by the second detecting means and  
25 receives the acknowledge from the second communication apparatus through the other channel.