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Slave terminal, monitoring system, and wireless transmission method

Abstract

A slave terminal includes: a data transmission unit that wirelessly transmits status data relating to a condition of a monitoring target to a monitoring apparatus in response to a transmission trigger at every fixed period; a reply check unit that determines whether or not an ACK signal was sent back from the monitoring apparatus in response to the status data that was transmitted; an adjustment value calculation unit that determines an adjustment period of a random length when there was no reply; a timing update unit that outputs a measurement start trigger after the adjustment period has elapsed when there was no reply, the timing update unit outputting the measurement start trigger without the adjustment period when there was a reply; and a trigger generation unit that outputs the transmission trigger after counting the fixed period in response to the measurement start trigger.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2007/0068240	12/2006	Watabe	73/146.5	B60C 23/0454
2010/0225357	12/2009	Priel	327/47	G06F 1/14
2014/0056286	12/2013	Nagata	N/A	N/A
2015/0031963	12/2014	Wright et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
H10-70756	12/1997	JP	N/A
2007-076457	12/2006	JP	N/A
4552813	12/2009	JP	N/A
2014-525738	12/2013	JP	N/A
2012/114738	12/2011	WO	N/A

OTHER PUBLICATIONS

Dec. 16, 2020 Office Action issued in Japanese Patent Application No. 2020-167796. cited by applicant

Mar. 22, 2021 Office Action issued in Japanese Patent Application No. 2020-167796. cited by applicant

Nov. 22, 2021 International Search Report issued in International Patent Application No. PCT/JP2021/033526. cited by applicant

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Background/Summary

TECHNICAL FIELD

(1) The present disclosure relates to a slave terminal that wirelessly transmits status data relating to a condition of a monitoring target to a master terminal, a wireless transmission method, and a monitoring system for monitoring physical conditions of livestock in which the livestock animals as monitoring targets are equipped with the slave terminal.

BACKGROUND ART

(2) One type of such a slave terminal, which wirelessly transmits data to a master terminal regularly, has hitherto been known (see, for example, Patent Document 1).

RELATED ART DOCUMENT

Patent Document

(3) Patent Document 1: Japanese Patent No. 4552813 (paragraph [0075] and FIG. 4)

SUMMARY OF THE INVENTION

Technical Problem to be Solved by the Invention

(4) The conventional slave terminal, in the case where a plurality of slave terminals is used per one master terminal, entailed problems such as cumbersome settings required for avoiding interference, and increased power consumption because of repeated wireless transmissions for avoiding interference. Accordingly, the present disclosure provides a technique that enables interference avoidance in a less cumbersome manner and with less power consumption than before.

Means of Solving the Problem

(5) A slave terminal according to a first aspect of the present disclosure made to solve the above problem is a slave terminal including: a data transmission unit that wirelessly transmits status data relating to a condition of a monitoring target to a monitoring apparatus in response to a transmission trigger at every fixed period; a reply check unit that determines whether or not an ACK signal was sent back from the monitoring apparatus in response to the status data that was transmitted; an adjustment value calculation unit that determines an adjustment period of a random length when the reply check unit has determined that there was no reply; a timing update unit that outputs a measurement start trigger after the adjustment period has elapsed when the reply check unit has determined that there was no reply, the timing update unit outputting the measurement start trigger without the adjustment period when the reply check unit has determined that there was a reply; and a trigger generation unit that outputs the transmission trigger after counting the fixed period in response to the measurement start trigger.

(6) A slave terminal according to a second aspect of the present disclosure is a slave terminal including: a data transmission unit that wirelessly transmits status data relating to a condition of a monitoring target to a monitoring apparatus in response to a transmission trigger at every fixed period; a reply check unit that determines whether or not an ACK signal was sent back from the monitoring apparatus in response to the status data that was transmitted; an adjustment value calculation unit that determines an adjustment period of a random length when the reply check unit has determined that there was no reply; a trigger generation unit that sequentially generates the transmission trigger at every fixed period; and a timing update unit provided to the trigger generation unit, the timing update unit shifting timings of generation of transmission triggers that are sequentially generated thereafter from a timing of generation of a current transmission trigger by the adjustment period when the reply check unit has determined that there was no reply.

(7) A wireless transmission method according to a third aspect of the present disclosure is a wireless transmission method for wirelessly transmitting status data relating to a condition of a monitoring target from a slave terminal to a monitoring apparatus at every fixed period, wherein when the slave terminal has received an ACK signal from the monitoring apparatus in response to a transmission of the status data, the status data to be sent thereafter at every fixed period is transmitted at a timing that is the same as a current transmission timing, whereas, when the slave terminal has not received an ACK signal, the status data to be sent thereafter at every fixed period

is transmitted at a timing that is shifted by a randomly determined adjustment period from a current transmission timing.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a schematic diagram illustrating an overall configuration of a monitoring system according to one embodiment of the present invention.

(2) FIG. **2** is a block diagram illustrating an electrical configuration of a slave terminal and a master terminal.

(3) FIG. **3** is a block diagram illustrating a control configuration of the slave terminal and master terminal.

(4) FIG. **4** is a time chart showing trigger generation timings.

(5) FIG. **5** is a flowchart of a first control program.

(6) FIG. **6** is a flowchart of a second control program.

(7) FIG. **7** is a block diagram illustrating a control configuration of a slave terminal and a master terminal according to a second embodiment.

(8) FIG. **8** is a time chart showing trigger generation timings.

(9) FIG. **9** is a flowchart of a first control program **1**V.

(10) FIG. **10** is a flowchart of a second control program **2**V.

MODE FOR CARRYING OUT THE INVENTION

First Embodiment

(11) A first embodiment of the monitoring system **100** according to the present disclosure will be described with reference to FIG. **1** to FIG. **6**. The monitoring system **100** of this embodiment shown in FIG. **1** includes a plurality of slave terminals **20** left in stomachs **10**S (specifically, first or second chamber of stomach) of a plurality of cows **10** that is to be monitored, a master terminal **30**, and a cloud server **50**. These are connected to each other via a communication network **101** including wireless base stations **400** and **401**, so that data relating to conditions of cows **10** wirelessly transmitted from the plurality of slave terminals **20** is received by the master terminal **30** and collected in the cloud server **50**. The master terminal **30** and cloud server **50** correspond to a “monitoring apparatus” in the claims.

(12) As shown in FIG. **2**, the slave terminal **20** is equipped with a pressure sensor **70**, a circuit board **71**, a battery **72**, etc., contained inside a waterproof case **73**. The pressure sensor **70** has a pressure-receiving surface that is exposed to the outside of the waterproof case **73**. A measurement unit **21** made up of the pressure sensor **70** and a measurement circuit **74** measures pressure inside the stomach **10**S, which is one of the conditions of the cow **10**.

(13) The circuit board **71** includes an oscillation circuit **75**, a wireless circuit **76**, a control circuit **77**, etc., mounted thereon. The oscillation circuit **75** has an oscillator as a main part, and provides the wireless circuit **76** and control circuit **77** with a periodic signal based on which carrier waves are sent or time is measured. The wireless circuit **76** sends and receives wireless signals and includes an antenna **29**, which is for example a coil antenna printed on the circuit board **71**. The control circuit **77** has a microcomputer **23** as a main part, which includes a CPU **23**A, a ROM **23**B, and a RAM **23**C. The ROM **23**B stores identification numbers assigned to respective slave terminals **20**, and first and second control programs PG**1** and PG**2** to be described later (see FIG. **5** and FIG. **6**). The CPU **23**A repeatedly executes the first and second control programs PG**1** and PG**2** in predetermined cycles to operate as control blocks such as a data transmission unit **22**, a trigger generation unit **25**, etc., in FIG. **3**.

(14) Pressure data measured by the measurement unit **21** of the slave terminal **20** is wirelessly transmitted by the wireless circuit **76** and received by the master terminal **30**. The master terminal

30, operable as a relay base station and a protocol converter, is installed in a cowhouse or farm, for example, where a plurality of cows **10** is being raised. The master terminal **30** sends the data transmitted from the slave terminal **20** to the cloud server **50** via a general-purpose communication line **300**. The cloud server **50** compares the pressure data sent from the plurality of slave terminals **20**, identifies the slave terminal **20** that has sent abnormal pressure data, for example, and sends a notification to a user terminal **60** owned by a livestock owner (see FIG. **1**). While one master terminal **30** is connected to one cloud server **50** in this embodiment, a plurality of master terminals **30** may be connected to one cloud server **50**, with the master terminal **30** being installed in each of cowhouses or farms, for example.

(15) The master terminal **30** includes a wireless circuit **31**, a control circuit **32**, a communication circuit **33**, and an oscillation circuit **34**. The control circuit **32** includes a CPU **32**A, a ROM **32**B, and a RAM **32**C, and executes a predetermined control program (not shown) stored in the ROM **32**B to operate as control blocks such as a data receiving and processing unit **35**A, an ACK signal transmission unit **35**B, etc., in FIG. **3**. The ROM **32**B also stores an identification number of the master terminal **30**.

(16) To be more specific, the trigger generation unit **25** of the slave terminal **20** shown in FIG. **3** includes a first trigger generation unit **25**A and a second trigger generation unit **25**B. The first trigger generation unit **25**A generates a first trigger TG**1** and gives it to the measurement unit **21**. The timing of generation of the first trigger TG**1** is set by a timing update unit **24**. To be more specific, upon receiving a measurement start trigger TG**3** from the timing update unit **24**, the first trigger generation unit **25**A generates the first trigger TG**1** after the elapse of a fixed period T**4** (e.g., 10 minutes). In response to this, the measurement unit **21** measures the pressure inside the stomach **10**S of the cow **10**. A status data generation unit **26** generates status data D**1** from the measurement result and gives it to the data transmission unit **22**.

(17) The data transmission unit **22** generates transmission data D**2** wherein an identification number of the slave terminal **20** and pressure data are stored in a data frame of a predetermined data length. Each time the first trigger TG**1** is generated, the second trigger generation unit **25**B sequentially generates the transmission trigger TG**2** delayed by a prescribed delay time Δt**1** from the first trigger TG**1**, and wirelessly transmits the transmission data D**2** using the wireless circuit **76**. The prescribed delay time Δt**1**, which is set to 0.6 seconds in this embodiment, is for securing time for the status data generation unit **26** to generate transmission data D**2**. Hereinafter the data transmission unit **22** sending transmission data D**2** shall mean the same as the data transmission unit **22** wirelessly transmitting transmission data D**2** using the wireless circuit **76**.

(18) When the data transmission unit **22** transmits transmission data D**2**, a reply check unit **27** determines whether or not the wireless circuit **76** has received an ACK signal sent in reply from the master terminal **30** before the elapse of a waiting period Δt**2**. Hereinafter, this will simply be expressed as the reply check unit **27** determining whether or not an ACK signal has been sent back. In this embodiment, the waiting period Δt**2** is set to 3 seconds, for example.

(19) The data receiving and processing unit **35**A of the master terminal **30** adds a receipt time to the data sent from each slave terminal **20** and received by the wireless circuit **31** of the master terminal **30** and sends the data to the cloud server **50**. The data receiving and processing unit **35**A extracts an identification number of the slave terminal **20** included in the transmission data from each slave terminal **20** and gives it to the ACK signal transmission unit **35**B. In response, the ACK signal transmission unit **35**B generates an ACK signal wherein the identification number of the slave terminal **20** and the identification number of the master terminal **30** are stored in a predetermined data frame, and wirelessly transmits the ACK signal via the wireless circuit **31**. This allows the reply check unit **27** of each slave terminal **20** to determine whether or not the transmission data D**2** was received by the master terminal **30** based on whether or not an ACK signal including the identification number of its own has been received.

(20) If the reply check unit **27** determines that no ACK signal was sent back, then an adjustment

value calculation unit **28** determines an adjustment period Rt of a random length. The adjustment period Rt is for causing the transmission timings to be shifted from one another when interference occurs at the time of reception at the master terminal **30**. Then, after the reply check unit **27** has determined that no ACK signal was sent back, when the adjustment period Rt has elapsed, the timing update unit **24** generates the measurement start trigger TG**3**, and gives the trigger to the first trigger generation unit **25**A. As mentioned above, upon receiving the measurement start trigger TG**3**, the first trigger generation unit **25** generates the first trigger TG**1** after the elapse of the fixed period T**4**.

(21) If the reply check unit **27** determines that an ACK signal was sent back, then the adjustment value calculation unit **28** sets the adjustment period Rt to "0." In this case, the timing update unit **24** generates the measurement start trigger TG**3** immediately after the determination that an ACK signal was sent back, and gives the trigger to the first trigger generation unit **25**A. Namely, when there is interference at the time of reception at the master terminal **30**, the timing of generation of the first trigger TG**1** by the first trigger generation unit **25**A is delayed by the adjustment period Rt compared to a case where there is no interference.

(22) When, after the generation of the first trigger TG**1** and elapse of the prescribed delay time Δt**1**, next transmission data D**2** is transmitted and the reply check unit **27** determines that no ACK signal was sent back, the adjustment value calculation unit **28** likewise sets a new adjustment period Rt of a random length. Therefore, the timing of generation of the measurement start trigger TG**3** to be given by the timing update unit **24** to the first trigger generation unit **25**A after that will be delayed by the new adjustment period Rt.

(23) The slave terminal **20** of this embodiment shifts the timing of sending transmission data D**2** in this way by delaying the timing of next measurement by the measurement unit **21** when there is no ACK signal in reply to the transmission data D**2** that has been sent, and repeats this change of timing until an ACK signal is sent back. This obviates the need for setting transmission timings for the plurality of slave terminals **20** such as to be shifted from one another beforehand, since the transmission timings of all the slave terminals **20** are scheduled in sequence such as not to overlap as the slave terminals **20** repeat transmissions.

(24) FIG. **4** illustrates a conceptual diagram of the timings of generation of various triggers described above. In FIGS. **4**, TG**1**, TG**2**, and TG**3** respectively represent the timings of generation of the first trigger TG**1**, the transmission trigger TG**2**, and the measurement start trigger. H**1** represents the timing at which the data transmission unit **22** transmits transmission data D**2**. The adjustment value calculation unit **28** and data transmission unit **22** mentioned above will be described in more detail below with reference to FIG. **4**.

(25) The adjustment value calculation unit **28** determines the adjustment period Rt such as to vary randomly by unit of a prescribed allocation length T**3** within a range of a prescribed maximum amplitude T**2**, after the transmission data D**2** has been sent and the waiting period Δt**2** has elapsed. In this embodiment, the prescribed maximum amplitude T**2** is set to 1 minute, for example, which is 1/10 of the fixed period T**4** (e.g., 10 minutes), and the prescribed allocation length T**3** is set to 0.6 seconds. That is, the adjustment value calculation unit **28** determines a value obtained by multiplying a random number selected from 100 random numbers (=1 minute/0.6 seconds) by 0.6, which is the prescribed allocation length T**3**, as the adjustment period Rt. In this embodiment, transmission data D**2** wirelessly transmitted by the data transmission unit **22** has a data length (i.e., data length of a data frame) of, for example, 0.37 seconds.

(26) In a concrete example of selecting one random number from 100 random numbers, for example, a value P of pressure measured by the measurement unit **21** is input to a random number generator function RAN(P) contained in the second control program PG**2** to be described later. To be more specific, for example, the random number generator function RAN(P) extracts upper four digits of the input value P of pressure, for example, and produces a random number by determining the remainder after dividing an integer consisting of numerals of the 4 digits by 100. In another

possible configuration, for example, a random number calculation IC may be mounted on the circuit board **71**, and the remainder after dividing a random number output by this IC by 100 may be determined as one of the 100 random numbers from 0 to 99.

(27) The data transmission unit **22** includes a carrier sense execution unit **22**C (see FIG. **3**). When the transmission trigger TG**2** is generated, the carrier sense execution unit **22**C performs a carrier sense before the transmission data D**2** is sent. When a transmission channel is determined to be available for the data transmission unit **22**, the transmission data D**2** is sent, and when no transmission channel is available, the data transmission unit does not send the transmission data D**2** and waits until a transmission channel becomes available. If no transmission channel is determined to be available until the elapse of time for transmission of the transmission data D**2** (0.37 seconds) from the generation of the transmission trigger TG**2**, the data transmission unit does not send the transmission data D**2**.

(28) The first and second control programs PG**1** and PG**2** (see FIG. **5** and FIG. **6**) executed by the CPU **23**A of the slave terminal **20** will be described below. The CPU **23**A executes the first and second control programs PG**1** and PG**2** every time it receives an interrupt signal at an interval of 0.6 seconds, for example, as a periodic signal output from the oscillation circuit **75**. “T**1**” in the first control program PG**1** represents a counter for counting the time. “FLG**1**, FLG**2**, FLG**3**” in the first and second control programs PG**1** and PG**2** represent flags, which are “0” in an initial state. “N**1**” represents a set value for determining the length of the fixed period T**4** mentioned above. In this embodiment, N**1** is set to 1000 (=ten minutes×60 seconds/0.6 seconds) so that the fixed period T**4** is 10 minutes. “R” represents a variable that stores the random number. The initial value of R is “0.” For convenience of explanation, R shall be referred to as random number hereinafter. TOF(FLG, X) included in the first and second control programs PG**1** and PG**2** is a function, which normally outputs “0.” When FLG changes from “0” to “1”, interrupt signals from the oscillation circuit **75** at an interval of 0.6 seconds are counted by an internal counter, and when the count result matches X, the function outputs “1.” MOD(T, N) included in the first control program PG**1** is a function that outputs a remainder after dividing T by N.

(29) As shown in FIG. **5**, the CPU **23**A executing the first control program PG**1** determines whether or not FLG**3** is “1” (S**11**), and if not “1,” then immediately exits the first control program PG**1** (NO at S**11**). Namely, the CPU **23**A in effect executes the first control program PG**1** only when FLG**3** is set to “1” in the first control program PG**1** (which corresponds to when the reply check unit **27** described above determines whether or not an ACK signal was sent back). If FLG**3** is “1” (YES at S**11**), then the CPU **23**A determines at step S**12** whether or not the number of counts of interrupt signals since FLG**3** was set to “1” from “0” has matched the random number R using the function TOF(FLG**3**, R). After the internal counter of the function TOF(FLG**3**, R) has counted R, the CPU increments the counter T**1** by 1 (S**13**), and determines whether or not FLG**1** is “1” (S**14**). If not “1” (NO at S**14**), the CPU determines whether or not the number of counts has matched N**1** (S**13**). If YES, then the CPU switches FLG**1** from “0” to “1” (S**16**), and executes a measurement step (S**17**). Here, the CPU **23**A executing step S**12** corresponds to the timing update unit **24** described above. Determining YES at step S**12** corresponds to generation of the measurement start trigger TG**3**. A value obtained by multiplying the random number R by 0.6 seconds, which is the period of interrupt signals, corresponds to the adjustment period Rt described above. The CPU **23**A executing step S**15** corresponds to the first trigger generation unit **25**A described above. Determining YES at step S**15** corresponds to generation of the first trigger TG**1**. Switching FLG**1** from “0” to “1” at step S**16** corresponds to the fixed period T**4** mentioned above having elapsed.

(30) After executing the measurement step (S**17**), the CPU **23**A operates as the status data generation unit **26**, i.e., receives a result of measurement by the pressure sensor **70** from the measurement circuit **74**, converts it into a digital signal, and generates pressure data.

(31) The CPU **23**A determines whether or not the remainder after dividing “counter T**1**” by N**1** is “1” (S**18**) after the execution of the measurement step (S**17**), and if YES, executes a transmission

step (S**19**). Here, the CPU **23**A executing step S**18** corresponds to the second trigger generation unit **25**B described above, i.e., the transmission trigger TG**2** is generated after the prescribed delay time Δt**1** (0.6 seconds) from the generation of the first trigger TG**1**.
(32) The CPU **23**A executing the transmission step (S**19**) corresponds to the data transmission unit **22**. In the transmission step (S**19**), the CPU generates transmission data D**2**, performs the carrier sense, and sends the transmission data D**2** as the data transmission unit **22** as described in the foregoing. Depending on the result of the carrier sense, the transmission data D**2** may not be sent due to interference.
(33) When the transmission step (S**19**) is executed, FLG**2** is set to "1" from "0," and FLG**1** is reset to "0" from "1" irrespective of whether or not the transmission data D**2** has been sent (S**20**, **21**). FLG**3** is reset to "0" from "1" (S**22**), and lastly the counter T**1** is reset to "0," whereupon the first control program PG**1** is ended (S**23**).
(34) As shown in FIG. **6**, the CPU **23**A executing the second control program PG**2** determines whether or not FLG**2** is "1" (S**24**), and if not "1," then immediately exits the second control program PG**2** (NO at S**24**). Namely, the CPU **23**A in effect executes the second control program PG**2** only when FLG**2** is set to "1" in the first control program PG**1** (only when the transmission step (S**20**) was executed). The CPU **23**A then determines whether or not the wireless circuit **76** of the slave terminal **20** has received an ACK signal (S**25**), and if an ACK signal has been received (YES at S**25**), resets FLG**2** to "0," sets FLG**3** to "1" from "0," and exits the second control program PG**2** (S**28**, **29**). Here, switching FLG**3** from "0" to "1" at step S**29** corresponds to the reply check unit **27** described above determining whether or not an ACK signal was sent back.
(35) When failing to receive an ACK signal (NO at S**25**), the CPU determines at step S**26** whether or not the number of counts of interrupt signals since FLG**2** was set to "1" from "0" has matched **5** using the function TOF(FLG**2**, **5**). The CPU waits for an ACK signal until the internal counter of the function TOF(FLG**2**,**5**) has counted **5**, i.e., until 3 seconds of the waiting period Δt**2** have passed after FLG**2** turned "1" (NO at S**26**). If no ACK signal was received after the elapse of 3 seconds after FLG**2** turned "1" (NO at S**25**, YES at S**26**), the CPU stores a value obtained by inputting the measurement result of pressure to the random number generator function RAN(P) mentioned above in the random number R (S**27**), resets FLG**2** to "0," sets FLG**3** to "1" from "0," and exits the second control program PG**2** (S**28**, **29**).
(36) The structure of the monitoring system **100** according to this embodiment has been described above. According to the monitoring system **100** that uses the plurality of slave terminals **20** of this embodiment, transmission data D**2** containing status data D**1** of a plurality of cows **10** that is to be monitored (data of pressure inside the stomachs **10**S) is sent at a certain interval to the master terminal **30** and accumulated in the cloud server **50**, so that changes in conditions of the plurality of cows **10** can be collectively monitored at the cloud server **50**.
(37) When all the slave terminals **20** send transmission data D**2** to the master terminal **30** at a fixed interval of time T**4**, a situation could arise where interference occurs due to overlapping transmission timings, causing the master terminal **30** to fail to receive transmission data D**2** from some or all of the slave terminals **20** and to send back an ACK signal to the slave terminals **20**.
(38) In the monitoring system **100** of this embodiment, the slave terminal **20** that did not receive an ACK signal sends transmission data D**2** at a timing shifted by delaying the timing of next measurement by the measurement unit **21** by a randomly determined adjustment period Rt. The adjustment period Rt is set to "0" for the slave terminal **20** that did receive an ACK signal so that the timing of next measurement by the measurement unit **21** is not shifted. This obviates the need for setting transmission timings for the plurality of slave terminals **20** such as to be shifted from one another beforehand, since the transmission timings of all the slave terminals **20** are scheduled in sequence such as not to overlap as the slave terminals **20** repeat transmissions. Namely, using the plurality of slave terminals **20** of this embodiment enables interference avoidance in a less cumbersome manner and with less power consumption than before.

(39) The slave terminal **20** of this embodiment can shift the transmission timings of slave terminals **20** from one another to avoid interference without changing the overall schedule of the plurality of slave terminals **20** to transmit status data D**1** at every fixed period T**4**, since the prescribed maximum amplitude T**2** of the adjustment period Rt is 1/10 or less of the fixed period T**4**. The adjustment period Rt is determined such as to vary randomly by unit of the prescribed allocation length T**3** within a range of the prescribed maximum amplitude T**2**. Since the prescribed allocation length T**3** is 1/100 of the prescribed maximum amplitude T**2**, it is possible to avoid interference for up to 100 slave terminals **20**.
(40) Failure to receive an ACK signal does not cause each slave terminal **20** to transmit again, which also helps avoid interference and reduce power consumption. Moreover, each slave terminal **20** transmitting after performing the carrier sense also helps avoid interference.
Second Embodiment
(41) This embodiment differs from the first embodiment in that the timing of measurement by the measurement unit **21** is set to arrive at every fixed period T**4** irrespective of whether or not an ACK signal was sent back to a slave terminal **20**V, and the transmission timing of transmission data D**2** is shifted by an adjustment period Rt that is randomly determined when no ACK signal was sent back. Only the features of the slave terminal **20**V of this embodiment that are different from those of the slave terminal **20** of the first embodiment will be described below.
(42) To be more specific, a trigger generation unit **25**V of the slave terminal **20**V includes a timing update unit **24**V, a first trigger generation unit **25**AV, and a second trigger generation unit **25**BV, as shown in FIG. **7**. The first trigger generation unit **25**AV generates a first trigger TG**1**V sequentially at every fixed period T**4** and gives it to the measurement unit **21**. Similarly to the first embodiment, the measurement unit **21** measures the pressure inside the stomach **10**S of the cow **10**, and the status data generation unit **26** generates status data D**1** from the measurement result and gives it to the data transmission unit **22**.
(43) The transmission trigger TG**2** is generated at a timing shifted from the first trigger TG**1**V by a period that is a sum of a prescribed delay time Δt**1** and an adjustment period Rt. To be more specific, each time the first trigger TG**1**V is generated, the second trigger generation unit **25**BV sequentially generates a second trigger TG**4** delayed from the first trigger TG**1**V by the prescribed delay time Δt**1**. In this embodiment, the prescribed delay time Δt**1** is set to 0.5 seconds.
(44) The adjustment period Rt is for causing the transmission timings to be shifted from one another when interference occurs at the time of reception at the master terminal **30**. The adjustment period Rt in the initial setting is “0,” for example. Each time a second trigger TG**4** is generated, the timing update unit **24**V generates a transmission trigger TG**2** delayed from the second trigger TG**4** by the adjustment period Rt. In the initial state, the second trigger TG**4** and transmission trigger TG**2** are the same. In response to the transmission trigger TG**2**, the data transmission unit **22** wirelessly sends the transmission data D**2**. When the data transmission unit **22** sends the transmission data D**2**, the reply check unit **27** determines whether or not the wireless circuit **76** received an ACK signal sent in reply from the master terminal **30** before the elapse of the waiting period Δt**2**. The waiting period Δt**2** is set to 10 seconds, for example, in this embodiment.
(45) If the reply check unit **27** determines that no ACK signal was sent back, then the adjustment value calculation unit **28** determines the adjustment period Rt of a random length. The transmission trigger TG**2** generated by the timing update unit **24**V after that is delayed from the second trigger TG**4** by the adjustment period Rt of a random length. In response to this transmission trigger TG**2**, the data transmission unit **22** sends the transmission data D**2**.
(46) When next transmission data D**2** is transmitted after the elapse of the fixed period T**4** (e.g., 10 minutes) from then and the reply check unit **27** determines that no ACK signal was sent back, the adjustment value calculation unit **28** likewise sets a new adjustment period Rt of a random length. The transmission trigger TG**2** generated by the timing update unit **24**V after that is delayed from the second trigger TG**4** by the new adjustment period Rt. In response to this transmission trigger

TG2, the data transmission unit 22 sends the transmission data D2.

(47) If the reply check unit 27 determines that an ACK signal was sent back, then the adjustment value calculation unit 28 maintains the adjustment period Rt to the same length rather than determining a new adjustment period Rt. Therefore, the transmission trigger TG2 generated by the timing update unit 24V after that is delayed from the second trigger TG4 by the adjustment period Rt that is the same length of the current adjustment period. In response to this transmission trigger TG2, the data transmission unit 22 sends the transmission data D2.

(48) FIG. 8 illustrates a conceptual diagram of the timings of generation of various triggers described above. TG1V, TG4, and TG2 respectively represent the timings of generation of the first trigger TG1V, the second trigger TG4, and the transmission trigger TG2.

(49) As shown in FIG. 8, the first trigger generation unit 25AV generates the first trigger TG1V at every fixed period T4, so that the timing of measurement by the measurement unit 21 is fixed to every fixed period T4 irrespective of whether an ACK signal was sent back or not. The adjustment value calculation unit 28 determines the adjustment period Rt such as to vary randomly by unit of the prescribed allocation length T3 within a range of the prescribed maximum amplitude T2, from the timing at which the status data generation unit 26 generates the transmission data D2 (timing of generation of the second trigger TG4). In this embodiment, the prescribed maximum amplitude T2 is set to 1 minute, for example, which is 1/10 of the fixed period T4 (e.g., 10 minutes), and the prescribed allocation length T3 is set to 0.1 second. That is, the adjustment value calculation unit 28 determines a value obtained by multiplying a random number selected from 600 random numbers (=1 minute/0.1 second) by 0.1, which is the prescribed allocation length T3, as the adjustment period Rt.

(50) In a concrete example of selecting one random number from 600 random numbers, similarly to the first embodiment, a value P of pressure measured by the measurement unit 21 is input to the random number generator function RAN(P) contained in the second control program PG2V to be described later. To be more specific, for example, the random number generator function RAN(P) extracts upper four digits of the input value P of pressure, for example, and produces a random number by determining the remainder after dividing an integer consisting of numerals of the 4 digits by 600. In another possible configuration, a random number calculation IC may be mounted on the circuit board 71, and the remainder after dividing a random number output by this IC by 600 may be determined as one of 600 random numbers from 0 to 599.

(51) The data length (i.e., data length of a data frame) of the transmission data D2 wirelessly transmitted by the data transmission unit 22 is set to 0.01 second, for example, which is 1/10 of the prescribed allocation length T3. The data transmission unit 22 includes the carrier sense execution unit 22C. When the transmission trigger TG2 is generated, the carrier sense execution unit 22C performs a carrier sense before the transmission data D2 is sent. When a transmission channel is determined to be available for the data transmission unit 22, the transmission data D2 is sent, and when no transmission channel is available, the data transmission unit does not send the transmission data D2 and waits until a transmission channel becomes available. If it is possible to finish transmitting the transmission data D2 within a period from the generation of the transmission trigger TG2 until the elapse of time of the prescribed allocation length T3, the data transmission unit sends the transmission data D2, and if not, the data transmission unit 22 does not send the transmission data D2. In the case where the data transmission unit 22 does not send the transmission data D2, the same processing is performed as that when transmission data D2 was sent and no ACK signal was sent back.

(52) In this embodiment, the CPU 23A of the slave terminal 20V executes first and second control programs PG1V and PG2V (see FIG. 9 and FIG. 10) corresponding to the first and second control programs PG1 and PG2 of the first embodiment. The first and second control programs PG1V and PG2V will be described below. The CPU 23A executes the first and second control programs PG1V and PG2V every time it receives an interrupt signal at an interval of 0.1 second, for example, as a

periodic signal output from the oscillation circuit **75**. In this embodiment, N**1** is set to 6000 (=ten minutes×60 seconds/0.1 second) so that the fixed period T**4** is 10 minutes. "FLG**4**" in the first control program PG**1**V represents a flag, which is "0" in the initial state.

(53) As shown in FIG. **9**, the CPU **23**A executing the first control program PG**1**V determines whether or not the remainder after dividing "counter T**1**+1" by 6000 is "1" (S**11**V), and if the remainder is "1" (YES at S**11**V), then executes a measurement step (S**12**V). Namely, the CPU **23**A executing this step S**11**V corresponds to the first trigger generation unit **25**AV described above. Determining YES at step S**11**V corresponds to generation of the first trigger TG**1**V.

(54) Upon executing the measurement step (S**12**V), the CPU **23**A operates as the status data generation unit **26**, i.e., receives a result of measurement by the pressure sensor **70** from the measurement circuit **74**, converts it into a digital signal, and generates pressure data.

(55) After executing the measurement step (S**12**V), the CPU **23**A determines whether or not FLG**4** is "1" (S**13**V), and if not "1" (NO at S**13**V), then determines whether or not the remainder after dividing "counter T**1**+1" by 6000 is "5" (S**14**V), and if YES, switches FLG**4** from "0" to "1." Here, switching FLG**4** from "0" to "1" corresponds to the generation of the second trigger TG**4** described above, and the CPU **23**A executing the step S**14**V described above corresponds to the second trigger generation unit **25**BV described above. Through steps S**13**V to S**15**V, the second trigger TG**4** is generated after the prescribed delay time Δt**1** (0.5 seconds) from the generation of the first trigger TG**1**V.

(56) When FLG**4** has switched from "0" to "1," the function TOF(FLG**4**, R) at step S**16**V determines whether or not the number of counts of interrupt signals from then has matched the random number R. Since the initial value of random number R is "0," the number of counts of interrupt signals matches the random number R immediately after FLG**4** has switched from "0" to "1," so that the function TOF(FLG**4**, R) outputs "1" (YES at S**16**V), and a transmission step (S**17**V) is executed. When the random number R is set to other values than "0," the transmission step (S**17**V) is executed after the elapse of time until the number of counts of interrupt signals since FLG**4** switched from "0" to "1" has matched the random number R. Namely, a value obtained by multiplying the random number R by 0.1 second, which is the period of interrupt signals, corresponds to the adjustment period Rt described above.

(57) Here, the CPU **23**A executing step S**16**V corresponds to the timing update unit **24**V described above. Determining YES at step S**16**V corresponds to generation of the transmission trigger TG**2**. The CPU **23**A executing the transmission step (S**17**V) corresponds to the data transmission unit **22**. In the transmission step (S**17**V), the CPU generates transmission data D**2**, performs the carrier sense, and sends the transmission data D**2** as the data transmission unit **22** as described in the foregoing. Depending on the result of the carrier sense, the transmission data D**2** may not be sent due to interference.

(58) When the transmission step (S**17**V) is executed, FLG**3** is set to "1" from "0," and FLG**4** is reset to "0" from "1" irrespective of whether or not the transmission data D**2** has been sent. (S**18**V, **19**V). The first control program PG**1**V lastly increments the counter T**1** by 1 (S**20**V) and is ended.

(59) As shown in FIG. **10**, the CPU **23**A executing the second control program PG**2**V determines whether or not FLG**2** is "1" (S**24**V), and if not "1," then immediately exits the second control program PG**2**V (NO at S**24**V). Namely, the CPU **23**A in effect executes the second control program PG**2**V only when FLG**2** is set to "1" in the first control program PG**1**V (only when the transmission step (S**17**V) was executed). The CPU **23**A then determines whether or not the wireless circuit **76** of the slave terminal **20**V has received an ACK signal (S**25**V), and if an ACK signal has been received (YES at S**25**V), resets FLG**2** to "0," and exits the second control program PG**2**V (S**28**V).

(60) When failing to receive an ACK signal (NO at S**25**V), the CPU determines at step S**26**V whether or not the number of counts of interrupt signals since FLG**2** was set to "1" from "0" has matched **100** using the function TOF (FLG**2**, **100**). The CPU waits for an ACK signal until the internal counter of the function TOF (FLG**2**, **100**) has counted **100**, i.e., until 10 seconds have

passed after FLG**2** turned “1” (NO at S**26**V). If no ACK signal was received after the elapse of 10 seconds after FLG**2** turned “1” (NO at S**25**V, YES at S**26**V), the CPU stores a value obtained by inputting the measurement result of pressure to the random number generator function RAN (P) mentioned above in the random number R, resets FLG**2** to “0,” and exits the second control program PG**2**V (S**28**V).

(61) According to the monitoring system **100** of this embodiment, the timing of measurement by the measurement unit **21** is set to arrive at every fixed period T**4** irrespective of whether or not an ACK signal was sent back, and the slave terminal **20**V that did not receive an ACK signal sends the transmission data D**2** at a timing shifted by the adjustment period Rt that is randomly determined. The slave terminal **20**V that did receive an ACK signal transmits at a timing that is the same as the current transmission timing. This configuration provides similar advantageous effects as those of the slave terminal **20** of the first embodiment.

(62) Since the prescribed maximum amplitude T**2** of the adjustment period Rt is 1/10 or less of the fixed period T**4** for the slave terminal **20**V of this embodiment, the transmission timings of slave terminals **20**V can be shifted from one another to avoid interference while the overall schedule of the plurality of slave terminals **20**V transmitting the status data D**1** at every fixed period T**4** is not changed. The adjustment period Rt is determined such as to vary randomly by unit of the prescribed allocation length T**3** within a range of the prescribed maximum amplitude T**2**. Since the prescribed allocation length T**3** is 1/600 of the prescribed maximum amplitude T**2**, it is possible to avoid interference for up to 600 slave terminals **20**V.

(63) Moreover, the slave terminal **20**V of this embodiment is able to prevent interference that may be caused by a transmission timing delayed due to the carrier sense, since the data transmission unit **22** transmits only when the period after the generation of the transmission trigger TG**2** and a determination by the carrier sense execution unit **22**C until the completion of transmission of the status data D**1** is shorter than the prescribed allocation length T**3**, which is set for the timing of generation of the transmission trigger TG**2** by the timing update unit **24**. Slave terminals **20**V that did not send transmission data D**2** due to interference in accordance with the result of the carrier sense, transmit at a timing shifted by a randomly determined adjustment period Rt after the fixed period T**4** thereafter, similarly to the slave terminals **2020**V that did not receive an ACK signal. Interference is thus avoided smoothly.

Other Embodiments

(64) (1) The prescribed maximum amplitude T**2** of the adjustment period Rt is set to 1/10 or less of the fixed period T**4** for the slave terminal **20** in the embodiments described above. As long as the prescribed maximum amplitude T**2** of the adjustment period Rt is shorter than the fixed period T**4**, the prescribed maximum amplitude T**2** may be set to any value. In the case where the transmission data D**2** from the plurality of slave terminals **20** is monitored at every fixed period T**4**, the prescribed maximum amplitude T**2** of the adjustment period Rt should preferably be ½ or less of the fixed period T**4**.

(65) (2) The slave terminal **20** in the above embodiments performs the carrier sense when sending the transmission data D**2**. Instead, the slave terminal may be configured to send the transmission data D**2** without carrier sensing.

(66) (3) The reply check unit **27** discards the transmission data D**2** to which it determined no ACK signal was sent back in the above embodiments. Instead, previous transmission data D**2** may be sent with new transmission data D**2** in the next transmission after the fixed period T**4**.

(67) (4) In the second embodiment, the timing of generation of a transmission trigger TG**2** is shifted forward or backward as the case may be from the current generation timing if no ACK signal is sent back. The generation timing may instead be either delayed only, or advanced only, from the current generation timing of the transmission trigger TG**2**.

(68) (5) The monitoring system **100** is used for monitoring livestock in the embodiments described above. The monitoring system **100** may be used for monitoring plants, conditions of various parts

of a vehicle, or conditions in a chemical plant.
(69) (6) Other sensors such as a temperature sensor or acceleration sensor may be connected to the measurement circuit **74** instead of or in addition to the pressure sensor **70** in the slave terminals **20** and **20**V to measure the body temperature or behavior as a condition of the cow **10**.
(70) In the case where an acceleration sensor is connected, the CPU **23**A of the slave terminal **20** or **20**V may be configured to integrate acceleration data measured by the acceleration sensor and acquired several times during a period in which pressure data or temperature data measured by the pressure sensor **70** or a temperature sensor is acquired once.
(71) While specific examples of the techniques included in the claims are disclosed in the specification and drawings, the techniques set forth in the claims are not limited to these specific examples but rather include various modifications and alterations of the specific examples, as well as partial extracts from the specific examples.
DESCRIPTION OF THE REFERENCE NUMERAL
(72) **10** Cow (livestock, monitoring target) **10**S Stomach **20**, **20**V Slave terminal **21** Measurement unit **22** Data transmission unit **22**C Carrier sense execution unit **24**, **24**V Timing update unit **25**, **25**V Trigger generation unit **26** Status data generation unit **27** Reply check unit **28** Adjustment value calculation unit **30** Master terminal (monitoring apparatus) **50** Cloud server (monitoring apparatus) **70** Pressure sensor **73** Waterproof case D**1** Status data D**2** Transmission data P Pressure PG**1** First control program PG**1**V First control program **1**V PG**2** Second control program PG**2**V Second control program **2**V Rt Adjustment period T**3** Prescribed allocation length (shifted period) T**4** Fixed period TG**2** Transmission trigger TG**3** Measurement start trigger ΔT**1** Prescribed delay time

Claims

1. A slave terminal comprising: a data transmission unit that wirelessly transmits status data relating to a condition of a monitoring target to a monitoring apparatus in response to a transmission trigger at every fixed period; a reply check unit that determines whether or not an ACK signal was sent back from the monitoring apparatus in response to the status data that was transmitted; an adjustment value calculation unit that determines an adjustment period of a random length when the reply check unit has determined that there was no reply; a timing update unit that outputs a measurement start trigger after the adjustment period has elapsed when the reply check unit has determined that there was no reply, the timing update unit outputting the measurement start trigger without the adjustment period when the reply check unit has determined that there was a reply; and a trigger generation unit that outputs the transmission trigger after counting the fixed period in response to the measurement start trigger.
2. The slave terminal according to claim 1, further comprising a carrier sense execution unit that performs a carrier sense every time the transmission trigger is generated and determines whether or not a channel to be used by the data transmission unit is available, the data transmission unit sending the status data on condition that the transmission trigger has been generated and the channel is determined to be available as a result of the carrier sense.
3. The slave terminal according to claim 1, wherein the data transmission unit does not transmit the status data again when the reply check unit determines that there was no reply.
4. The slave terminal according to claim 1, wherein the adjustment period has a maximum absolute value that is ½ or less of the fixed period.
5. The slave terminal according to claim 1, further comprising a measurement unit that measures a condition of the monitoring target, and a status data generation unit that generates the status data based on a measurement result of the measurement unit.
6. A slave terminal comprising: a data transmission unit that wirelessly transmits status data relating to a condition of a monitoring target to a monitoring apparatus in response to a

transmission trigger at every fixed period; a reply check unit that determines whether or not an ACK signal was sent back from the monitoring apparatus in response to the status data that was transmitted; an adjustment value calculation unit that determines an adjustment period of a random length when the reply check unit has determined that there was no reply; a trigger generation unit that sequentially generates the transmission trigger at the every fixed period; and a timing update unit provided to the trigger generation unit, the timing update unit shifting timings of generation of the transmission triggers that are sequentially generated thereafter from a current timing of generation of the transmission trigger by the adjustment period when the reply check unit has determined that there was no reply.

7. The slave terminal according to claim 6, wherein, each time the reply check unit determines that there was no reply, the timing update unit updates timings of generation of the transmission triggers that are sequentially generated thereafter either by only delaying or advancing the timings from the current timing of generation of the transmission trigger.

8. The slave terminal according to claim 7, further comprising a carrier sense execution unit that performs a carrier sense every time the transmission trigger is generated and determines whether or not a channel to be used by the data transmission unit is available, the data transmission unit sending the status data on condition that the transmission trigger has been generated and the channel is determined to be available as a result of the carrier sense, the data transmission unit sending the status data only when a period after generation of the transmission trigger and a determination by the carrier sense execution unit until completion of transmission of the status data is shorter than a minimum unit of time for shifting a timing of generation of the transmission trigger by the timing update unit.

9. The slave terminal according to claim 6, further comprising a carrier sense execution unit that performs a carrier sense every time the transmission trigger is generated and determines whether or not a channel to be used by the data transmission unit is available, the data transmission unit sending the status data on condition that the transmission trigger has been generated and the channel is determined to be available as a result of the carrier sense, the data transmission unit sending the status data only when a period after generation of the transmission trigger and a determination by the carrier sense execution unit until completion of transmission of the status data is shorter than a minimum unit of time for shifting a timing of generation of the transmission trigger by the timing update unit.

10. The slave terminal according to claim 6, wherein the data transmission unit does not transmit the status data again when the reply check unit determines that there was no reply.

11. The slave terminal according to claim 6, wherein the adjustment period has a maximum absolute value that is ½ or less of the fixed period.

12. The slave terminal according to claim 6, further comprising a measurement unit that measures a condition of the monitoring target, and a status data generation unit that generates the status data based on a measurement result of the measurement unit.

13. A wireless transmission method for wirelessly transmitting status data relating to a condition of a monitoring target from a slave terminal to a monitoring apparatus at every fixed period, wherein when the slave terminal has received an ACK signal from the monitoring apparatus in response to a transmission of the status data, the status data to be sent thereafter at the every fixed period is transmitted at a same timing as a current transmission timing, whereas, when the slave terminal has not received the ACK signal, the status data to be sent thereafter at the every fixed period is transmitted at a timing that is shifted by a randomly determined adjustment period from the current transmission timing.