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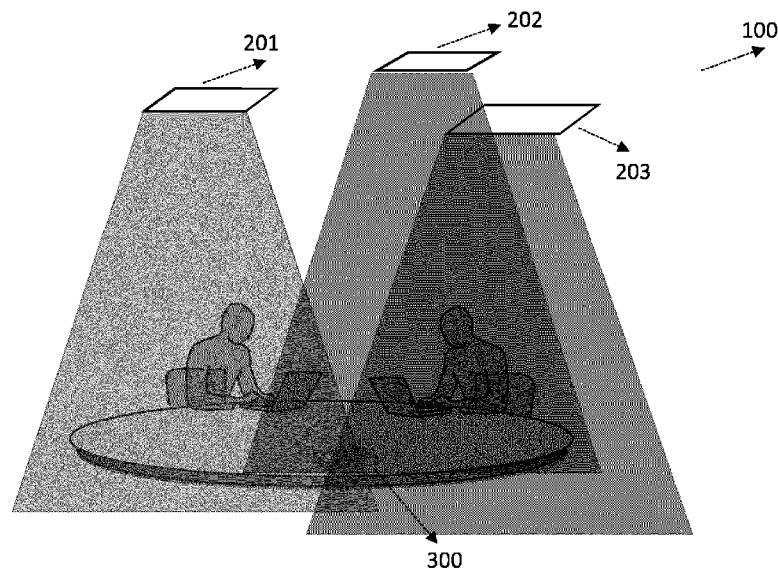


FIG. 1

(57) Abstract: This present invention relates to a distributed ionization monitoring system (100) comprising a first air ionizer (201) configured to generate and emit a first stream of ionized air molecules, wherein the first stream is modulated using a unique signature of the first air ionizer; a second air ionizer (202) configured to generate and emit a second stream of ionized air molecules, wherein the second stream is modulated using a unique signature of the second air ionizer; and a remote ion detection apparatus (300) configured to measure ion concentration over time; and determine a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.

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SYSTEMS AND METHODS FOR REMOTE MONITORING OF AIR IONIZATION

FIELD OF THE DISCLOSURE

The present disclosure is directed generally to systems and methods for monitoring of air ionization status. More particularly, the present disclosure is directed to systems and methods for monitoring of multiple co-existing air ionizers from remote.

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BACKGROUND

The pandemic outbreak of COVID-19 has exposed an urgent need to improve the systems and methods used to fight infectious diseases, particularly those diseases that are transmitted from human-to-human via short distance particle transmission and surface transmission. Viruses and viral materials can survive for days on surfaces such as desks, tables, chairs, stainless steel door handles, etc. Air purifying devices that include ionizing generators are known solutions to drastically reduce bacteria and viruses in air when the air ion density is at the correct level. Previously, air ionization was mainly applied in industrial sites for particle control and in private homes for air quality optimization. Recently, in view of the pandemic situations, air ionization treatment is required in many more scenarios, such as in shopping malls, office buildings, and other public areas.

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The effectiveness of air ionization is based on an adequate ion density in the air. However, the performance of ionizers is subject to many factors, such as drift of power supply, contamination of electrodes, degradation of electrodes or other system components. Furthermore, the distribution of the ions across the room also depends on the airflow in the room, which is influenced by complex factors, such as actuation of HVAC equipment, open/close status of the door and windows, position of furniture, and the temperature profile of the room. Thus, in order to improve air quality, it is necessary to monitor air ionization status regularly.

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US6507473B2 is related to an ionization system for a predefined area comprising a plurality of emitter modules spaced around the area, a system controller for monitoring and/or controlling the emitter modules, and a communication medium or electrical lines which electrically connect the plurality of emitter modules with the system

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controller. The sophisticated monitoring and feedback system may satisfy critical application requirements, such as in an industrial or cleanroom environment.

EP2467273A1 is related to a method for controlling an ionization device for ionizing air for the ventilation of interior spaces, such as motor vehicle interior spaces. The ionization device releases ions of a first ion type at least intermittently.

SUMMARY OF THE INVENTION

The inventors recognize that with the large deployment of ionization generators or ionizers in buildings, a cost-efficient ionization monitoring system is needed.

Furthermore, for the maintenance purpose of the large number of ionizers, it is even more beneficial that the monitoring system is capable to detect and diagnose the status or impact of an individual ionizer.

The present invention is directed to inventive systems and methods for an efficient monitoring of ionization status from remote. In particular, a low cost and low complexity ionization monitoring system is disclosed, where a single ion detection apparatus is placed to monitor one or more ionizers remotely. The ion detection apparatus detects overlaid streams of ionized molecules generated by the one or more ionizers in the detection area. In order to pinpoint the performance of an individual ionizer out of the plurality of ionizers, it is proposed that each ionizer modulates ionized air molecules with a unique signature dedicated to that ionizer. Thus, by identifying a unique signature embedded in a modulated stream, the remote ion detection apparatus is able to distinguish such a modulated stream from the rest.

In accordance with a first aspect a distributed ionization monitoring system is provided. The distributed ionization monitoring system comprising a first air ionizer configured to generate and emit a first stream of ionized air molecules, wherein the first stream is modulated using a unique signature of the first air ionizer; a second air ionizer configured to generate and emit a second stream of ionized air molecules, wherein the second stream is modulated using a unique signature of the second air ionizer; and a remote ion detection apparatus configured to measure ion concentration over time; determine a contribution from a modulated stream of ionized air molecules to the ion concentration by detecting a unique signature embedded in the modulated stream.

In general, an ionizer may be configured to generate a stream or flow of ionized molecules in either an un-modulated mode or a modulated mode. In order to allow a remote ion detection apparatus to detect the ionization status of an individual ionizer, it is

necessary for the individual ionizer to operate in the modulated mode. When the ionizer is operating in the modulated mode, the unique signature dedicated to the ionizer is embedded in the modulated stream to specify its identity. The modulation may be applied to an ionizer according to different time constants, such as continuously, periodically, or during a period of time. The choice among different options may be related to how frequently the remote ion detection apparatus will take the measurement. The modulation may also be applied to an ionizer upon a request received by the ionizer from a remote ion detection apparatus, a remote controller, or another controller or processor connected to the ionizer.

The unique signature is a unique identifier to distinguish an individual ionizer from the rest of a plurality of ionizers co-located in the area. Preferably, such unique signatures are binary code sequences, and even more beneficially, such binary code sequences are orthogonal to each other.

To reduce the system cost and for ease of deployment, a single ion detection apparatus may be deployed to monitor multiple ionizers from remote. Therefore, the ion detection apparatus may be located in the overlapping area that ionized molecules originated from the multiple ionizers will travel to. The ion detection apparatus measures the ion concentration resulted from overlaid streams or flows of ionized molecules from multiple ionizers, and then determines a contribution from an individual modulated stream out of the overlaid streams by detecting a unique signature embedded in that modulated stream. In this way, the remote ion detection apparatus can measure the number of ionized molecules belonging to a single modulated stream individually. The detected unique signature is also used by the remote ion detection apparatus to identify a certain ionizer from which that modulated stream originated. Therefore, by identifying one or more modulated streams out of the overlaid streams, the ion detection apparatus obtains an overview of ionization performance of the corresponding one or more ionizers.

Advantageously, the remote ion detection apparatus is further configured to infer, according to the determined contribution, an air ionization status of an air ionizer that generates the modulated stream.

The air ionization status of an air ionizer provides an indication on the operational state and/or operation performance of an individual ionizer. Since the ion detection apparatus is remote from the individual ionizer, an estimation model may be used to derive the operation performance of an ionizer by taking an environmental parameter into account, such as the distance between the ion detection apparatus and the ionizer, which may

be registered at commissioning or be determined in situ by the devices involved (e.g., using a radio signal strength measurement).

Beneficially, the distributed ionization monitoring system further comprises a central controller; wherein the remote ion detection apparatus is further configured to send the air ionization status to the central controller.

A local ion generation and monitoring system comprising a plurality of ionizers and a single remote ion detection apparatus may be located in a single room, such as a meeting room or office room, in a building. It is advantageous to allow a building automation system to collect information from more than one local ion generation and monitoring system to derive an overall picture of the entire building. Therefore, preferably the remote ion detection apparatus is further configured to send the air ionization status to a central controller.

In accordance with a second aspect an air ion generating subsystem is provided. The air ion generating subsystem comprising a first air ionizer configured to generate and emit a first stream of ionized air molecules, wherein the first stream is modulated using a unique signature of the first air ionizer; and a second air ionizer configured to generate and emit a second stream of ionized air molecules, wherein the second stream is modulated using a unique signature of the second air ionizer.

It is preferable to use an air ion generation subsystem that comprises more than one ionizer, which can share certain facilities belonging to the same subsystem to reduce the overall cost for controlling the ionizers according to the present invention.

In a preferred example, the air ion generating subsystem further comprises a processor, the processor configured to determine the unique signatures for the first and the second air ionizers; generate ion generation control signals based on a configuration parameter and the unique signatures; and control the first and the second air ionizers with the corresponding ion generation control signal.

A unique signature may be generated by the processor for each ionizer or derived based on a known unique identifier of the ionizer. The unique signature may also be a predefined identifier dedicated to a factory new ionizer. A further option is that the unique signature is received from a commissioning device during installation or is assigned in-situ from an overall controller, much like in dynamic address assignment schemes used for network address assignment.

An ion generation control signal is generated by the processor for each ionizer according to the configuration parameter and the unique signature. In a possible

implementation, the ion generation control signal is applied to control a driver circuit in an ionizer, and the driver circuit may be either an AC type or DC type of driver.

Preferably, the configuration parameter is related to at least one of: a selection between a modulated mode and an unmodulated mode, a time schedule on using the modulated mode and the unmodulated mode, a first setting on a modulation frequency, a second setting on a pulse slope, and a third setting on an amplitude.

The operation of an ionizer is configurable via the configuration parameter. The ionizer may be configured to operate in either a modulated mode or an unmodulated mode or be configured to operate alternately between a modulated mode and an unmodulated mode according to a time schedule. Further settings can be provided with regard to the modulation frequency, the pulse slope and the amplitude.

Each ionizer may be modulated according to a different combination of modulation frequency, pulse slope and amplitude. In a preferred example, the unique signature is embedded in a stream of ionized molecules to characterize a modulated stream.

In a preferred example, the unique signatures are binary code sequences, and the first air ionizer and the second air ionizer are configured to suppress, respectively, a set of pulses in the first stream and the second stream according to their respective binary code sequences.

In another example, the first air ionizer and the second air ionizer are configured to control, respectively, the amplitude of the first stream and the second stream according to their respective unique signatures.

Beneficially, the unique signatures of different ionizers have a low cross correlation value, which may simplify the processing at a remote ion detection apparatus side to distinguish one modulated stream from another.

Advantageously, the air ion generating subsystem further comprises a radio, and the radio is configured to receive a feedback signal from a remote ion detection apparatus, and the processor is further configured to adjust at least one of the ion generation control signals according to the feedback signal.

The radio comprises at least a receiver to receive on a wireless communication channel for a feedback signal from the remote ion detection apparatus. The feedback signal is encapsuled in a wireless communication message or packet according to a certain wireless communication protocol, such as Zigbee, Bluetooth, BLE, Wi-Fi, or another short-range wireless communication protocol. Depending on what is addressed in the feedback signal, the processor may adjust the one or more ion generation control signals of the one or more

ionizers accordingly. Such a feedback control loop helps to improve performance of the ionization system.

Beneficially, the feedback signal comprises information related to at least one of: a remotely detected air ionization status, a list of detected unique signatures, ion concentration, a type of ions, a speed of air flow of a predefined area, occupancy information of the predefined area, an activity in the predefined area, and room state information.

The predefined area may be the room comprising the system, or a certain coverage area of the ionization system taking effect. The room state information may be related to window/door open/close status, temperature/humidity information of the room.

Occupancy information may for example be used to ascertain whether the air ionization with the room is adequate for the current occupancy state. It may also be interesting to know about the activity in the room. For example, if there is a high-risk activity such as a workout, higher ion concentration may be needed.

Preferably, the feedback signal is related to at least one remotely detected air ionization status. The at least one remotely detected air ionization status is an individual ionization status of an individual stream corresponding to a unique signature embedded in the individual stream. The feedback signal may comprise one or more remotely detected air ionization statuses of the one or more ionizers comprised in the air ion generating subsystem. Furthermore, the feedback signal may provide further information to assist the processor to adjust ion generation control signals adaptively to environmental or context parameters. A list of detected unique signatures may also be included in the feedback signal. Since each ionizer comprised in the air ion generating subsystem has a unique signature, the list may help the air ion generating subsystem to identify if all the ionizers are functioning.

Ions can be either positive or negative. Positive ions may have negative impact on human, such as to impair brain function and suppress the immune system causing symptoms such as: anxiety, breathing difficulty, fatigue, headaches, irritability, lack of energy, poor concentration, nausea, and vertigo. In contrast, negative ions have positive impact on human health. Therefore, the overall polarity of ions or type of ions may also be a relevant parameter to be obtained for a better control of the ion generation subsystem.

As one example, with an open window, the inflow of outdoor fresh air may also have impact on the level of ions in the room. As compared to typical indoor environment, average air ions of both positive and negative polarities are higher with outdoor fresh air. Therefore, it may be preferable to reduce the ionizer activity when the window is open, such as reducing the amount of ionized air molecules generated.

In accordance with a third aspect a remote ion detection apparatus is provided. The remote ion detection apparatus is configured to measure ion concentration over time; determine a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.

5 From a user perspective, it is interesting to know the average ionization level in the room, which represents an indication about air quality. To provide such information, the remote ion detection apparatus is configured to measure ionized air molecules over time. Thus, the remote ion detection apparatus is able to judge if there is sufficient ion concentration arriving its vicinity to locally provide reliable disinfection and/or increase of
10 human comfort.

From a building automation and management point of view, it is even more interesting to monitor and diagnose each ionizer individually. The remote ion detection apparatus is configured to identify a modulated stream of ionized molecules from an individual ionizer with the aid of a unique signature embedded in the stream. The total ion
15 concentration detected at the remote ion detection apparatus may result from one or more overlaid streams generated by different ionizers. In order to quantify the performance of an individual ionizer, it is necessary to determine the individual contribution separately.

In a big room, such as an open plan office, more than one remote ion detection apparatus may be needed to capture the ionization conditions. The detection information
20 obtained by different remote ion detection apparatuses may be exchanged or collected to derive an overview with regard to how much each ionizer contributes to a local area in the big room. Such information may be used to derive an improved deployment scheme of the ionizers in order to achieve a uniform ion distribution in the area.

Preferably, the remote ion detection apparatus is further configured to identify,
25 according to the determined contribution, an air ionization status of an air ionizer that generates the modulated stream.

Beneficially, the remote ion detection apparatus further comprising a user interface to display information of the air ionization status and/or the ion concentration.

The information related to the air ionization status of a single air ionizer and/or
30 the overall ion concentration may be displayed by the remote ion detection apparatus via a visual indicator, a light, or a text message on a display. Such a user interface provides a direct feedback to the user about the effectiveness of the ionization system.

Advantageously, the remote ion detection apparatus further comprises a radio to send a feedback signal, wherein the feedback signal is related to at least one of: identified ionization status, a unique signature detected, ion concentration, and a type of ions.

Ions can be either positive or negative. Positive ions may have negative impact on human, while negative ions are beneficial to human health. Therefore, the overall polarity of ions or type of ions may also be a relevant parameter to be identified and reported. The radio of the remote ion detection apparatus comprises at least a transmitter to send a feedback signal over a wireless communication channel. The feedback signal is encapsulated in a wireless communication message or packet according to a certain wireless communication protocol, such as Zigbee, Bluetooth, BLE, Wi-Fi, or another short-range wireless communication protocol. The feedback signal may be sent to a remote ionization subsystem or a remote central controller of a building management system.

In a preferred example, the remote ion detection apparatus further comprises a sensor to detect a further parameter related to a predefined area, and wherein the further parameter is related to at least one of: a speed of air flow of the predefined area, occupancy information of the predefined area, an activity in the predefined area, room state information; and the remote ion detection apparatus is further configured to take the further parameter into consideration when identifying the air ionization status of the air ionizer.

The predefined area may be the room comprising the system, or a certain coverage area of the ionization system taking effect. The room state information may be related to window/door open/close status, temperature/humidity information of the room.

Environmental or context information detected by the sensor may be used by the remote ion detection apparatus to have more accurate judgement on the ion concentration level and the ionization performance of the air ionizer.

Preferably, the radio is further configured to include the further parameter in the feedback signal.

The further parameter may also be included in the feedback signal to allow a remote ionization subsystem or a remote central controller to have more insight in control the ionization system based on the real-time environmental or context information.

In accordance with a fourth aspect a method of an air ion generating subsystem is provided. The method comprises the air ion generating subsystem: generating and emitting a first stream of ionized air molecules via a first air ionizer, wherein the first stream is modulated using a unique signature of the first air ionizer; generating and emitting a

second stream of ionized air molecules via a second air ionizer, wherein the second stream is modulated using a unique signature of the second air ionizer.

In accordance with a further aspect an air ionization monitoring method is provided. An air ionization monitoring method of a remote ion detection apparatus, the method comprises remote ion detection apparatus: measuring ion concentration over time; determining a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.

In accordance with a further aspect, a computer program is provided, comprising code means which, when the program is executed by an air ion generating subsystem comprising processing means, cause the processing means to perform the method of the air ion generating subsystem according to the present invention.

In accordance with a further aspect, a computer program is provided comprising code means which, when the program is executed by a remote ion detection apparatus comprising processing means, cause the processing means to perform the method of the remote ion detection apparatus according to the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, like reference characters generally refer to the same parts throughout the different figures. Also, the drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

FIG. 1 illustrates a distributed ionization monitoring system;

FIG. 2 schematically depicts basic components of an air ion generation subsystem;

FIG. 3 schematically depicts basic components of a remote ion detection apparatus;

FIG. 4(a) shows a flow chart of a method of an air ion generation subsystem; and

FIG. 4(b) shows a flow chart of an air ionization monitoring method of a remote ion detection apparatus.

DETAILED DESCRIPTION OF EMBODIMENTS

Embodiments contemplated by the present disclosure will now be described in more detail with reference to the accompanying drawings. The disclosed subject matter should not be construed as limited to only the embodiments set forth herein. Rather, the

illustrated embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

The present disclosure is detailed below with reference to efficient air ionization monitoring from remote.

5 FIG. 1 provides an example of a distributed ionization monitoring system 100. The distributed ionization monitoring system 100 comprises more than one ionizer or ionizing means 201, 202, 203, and a remote ion analyzer or detection apparatus 300.

10 The more than one ionizer or ionizing means 201, 202, 203 is individually configured to generate and emit ionized air molecules. The ionizers or ionizing means may operate in a modulated mode or unmodulated mode. The inventors propose to apply modulation on the ionizing means or ionizers in order to identify any defective or underperforming ionizer modules or to recognize if ions no longer successfully reach the target disinfection area/volume despite of sufficient ions being generated at the ionizing means; e.g., as a result of air-flow blockage. Therefore, the ionizers 201, 202, 203 are further
15 configured to generate and emit modulated ionizing streams each with a unique signature embedded to serve remote monitoring purpose.

Each ionizer may normally work in a non-modulated way and generate a constant ion current. According to a certain time constant or schedule, or upon a request, an ionizer starts emitting ion streams with a modulation pattern, such that the unique signature is
20 embedded in the streams. When the modulated streams are short compared to a pause time between adjacent streams, it can be assumed that collisions between different wave peaks are seldom, and each unique signature can be read out from the ion wave peaks and valleys reaching a remote ion analyser or detection apparatus 300 after some time.

Preferably, the ionizers 201, 202, 203 are ceiling-based ionizing means. The
25 remote ion analyzer or detection apparatus 300 is located remotely to the ionizers or ionizing means 201, 202, 203. The remote ion analyzer or detection apparatus 300 may be deployed close to the user, such as on a target disinfection surface. As exemplarily demonstrated in FIG. 1, the distributed ionization monitoring system 100 is located in a meeting room, with the ionizers 201, 202, 203 deployed on the ceiling and the remote ion detection apparatus 300
30 placed on the table next to the users. Shadowed trapezoids exemplarily illustrate the propagation areas that ionized molecules originated from each ionizer or ionizing means 201, 202, 203 may travel. Adjacent ionizers are typically deployed dense enough to guarantee sufficient ionization coverage. In practice, because of air flow or people movement, the propagation area of ionized molecules from a same ionizer may change temporally and

spatially. A plurality of ionizers or ionizing means contribute to an overlaid ionizing effect in the space.

The remote ion detection apparatus 300 measures ion concentration over time, which provides an indication of the overall air ionization level at its location. This measurement may give users of the space the direct feedback ion concentration is good for a safe meeting, when sufficient ions have recently reached the surface to ensure that it is disinfected. Thus, the remote ion detection apparatus 300 may provide a visual indicator or a text display about ion concentration or ionization level on the apparatus.

For monitoring and diagnostic purpose of the ionization system, it is even more interesting if the performance of an individual ionizer can be characterized. The remote ion detection apparatus 300 is further configured to determine a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream. Hence, the coded ion streams enable the remote ion detection apparatus 300 to extract a single modulated stream out of a plurality of overlaid ion streams. Hence, each operating ionizer contributing to the disinfection of a specific task area can be identified remotely and its relative contribution can be determined, and then the performance of an individual ionizer can be derived. Such information may be provided as a feedback signal to the individual ionizer for calibration purpose or sent to a central control for the control and diagnosis purpose of the ionization system.

FIG. 2 schematically depicts basic components of such an air ion generation subsystem 220. The air ion generation subsystem 220 comprises more than one ionizer or ionizing means 201, 202, which may share certain auxiliary components of the subsystem. The more than one ionizer or ionizing means 201, 202 are configured to generate and emit modulated streams of ionized air molecules with unique signatures dedicated to each individual ionizer 201, 202 embedded in the corresponding streams. The air ion generation subsystem 220 further comprises a processor or controller 230, which is shared by all the ionizers or ion generating means 201, 202 comprised in the same sub-system. The unique signature of an ionizer 201, 202 may be hard coded in the ionizer during manufacturing. The unique signature may also be determined by the processor 230 for each ionizer individually, such as derived based on a known unique identifier or address of each ionizer or generated according to a pseudorandom process. Another option is that the unique signature is received by the processor for each ionizer from a commissioning device during installation. One further option is that the unique signature is configured by the processor 230 for each ionizer upon a command received from a central controller of a building management system.

The processor 230 is further configured to control each ionizer 201, 202 via an individual ion generation control signal, which is generated by the processor 230 for each ionizer according to a configuration parameter and the unique signature. The configuration parameter is related to one or more settings of an ionizer's operation, which may be a selection between a modulated mode and an unmodulated mode, a time schedule on using the modulated mode and the unmodulated mode, a setting on a modulation frequency, a setting on a pulse slope, or another setting on an amplitude of the pulse. The ionizer may be configured to operate in either a modulated mode or an unmodulated mode or be configured to operate alternately between a modulated mode and an unmodulated mode according to a time schedule. Each ionizer may be modulated according to a different combination of modulation frequency, pulse slope and amplitude. In a possible implementation, the ion generation control signal is applied to control a driver circuit in an ionizer, and the driver circuit may be either an AC type or DC type of driver.

In a preferred example, the unique signature is embedded in a stream of ionized molecules to characterize a modulated stream. A unique signature may be a binary code sequence, and an air ionizer 201, 202 may be configured to suppress a set of pulses in a stream of ionized molecules according to the binary code sequence.

In another example, the modulation is not done by influencing the pattern of discharge pulses but by modifying the amplitude of the ion wave emitted by the ionizer, such as modulating the set value of the power supply supplying a pulse generator in the ionizer.

In another preferred example, for the multiple ionizers 201, 202 located in the same room or at least belonging to the same ion generation apparatus 220, the unique signatures are chosen such that the cross correlation of the modulation streams between different ionizers in the space is low, which allows the ion analyzer or detection apparatus 300 to separate different contributions with reduced complexity. In a preferred implementation the unique signatures are binary code sequences that are orthogonal to each other. This embodiment may be especially helpful when the modulation speed is very low (advantageous if the ions travel very slowly due to a lack of air movement in the room and hence the peaks and valleys become less sharply defined) and hence the transmission of a single coded ion stream takes longer time.

Optionally, the air ion generation subsystem 220 further comprises a radio 240. The radio 240 is operating at least as a receiver, which is configured to receive a feedback signal from a remote ion analyzer or detection apparatus by means of RF communication, such as according to a Bluetooth, BLE, Zigbee, or Wi-Fi communication

protocol. The feedback signal may be used for a calibration or diagnostic purpose. The feedback signal comprises information related to at least one of: a remotely detected air ionization status, a list of detected unique signatures, a speed of air flow of a predefined area, occupancy information of the predefined area, and room state information.

5 In one example, the feedback signal may indicate a performance degradation of one or more ionizers comprised in the ion generation subsystem 220, and thus the control of the related ionizers may be adjusted accordingly. Furthermore, if no feedback signal is received regarding a certain ionizer after a couple of transmissions of a modulated ion wave or stream by that ionizer, the processor may assume that ionizer is not meaningfully
10 contributing to the ionization density at the remote analyzer or a target surface. Hence, the processor may control that ionizer to light up a signal LED on the ionizer to give a warning of potential problem. Alternatively, or in addition, the radio 240 is further configured to send a message to a central controller of an air control or building management system about the mal function of that ionizer. Service personnel may be automatically informed thereon to
15 bring exchange ionizer modules. A location map corresponding to the deployment of the ion generation apparatus may help the service person to locate the failing device efficiently.

In another example, after receiving a feedback signal, the air ion generation subsystem may be reconfigured so that certain ionizers are configured to increase the gap between emitting two adjacent modulated streams with unique signatures embedded. In this
20 way, the pauses between transmissions of modulated streams get extended and thus the measurement noise floor at the remote ion analyzer or detection apparatus 300 for identifying different ionizers 201, 202 can be reduced.

Upon receiving a list of detected unique signatures in the feedback signal, the ion generation apparatus 220 may evaluate if a certain unique signature of an ionizer is
25 missing from the list. Beneficially, upon the latency between emitting a modulated stream and a feedback signal related to that modulated stream, the processor 230 may adjust the modulation frequency of a corresponding ionizer 201, 202 according to an estimated travel time of the ions from the ionizer 201, 202 to the ion detection apparatus 300, assuming that the delay due to the measurement done by the ion detection apparatus 300 is negligible as
30 compared to the travel time of ions. Optionally, the processor 230 may further take a bandwidth derived from both the specific ionizer model and detection apparatus model into account. Thus, the selection of an appropriate coded-ion modulation frequency can be either done by collecting the related information from all ionizers or by characterizing the bandwidth of each coded-ion communication channel between an ionizer unit 201, 202 and

the detection apparatus 300 over an extended period of operation. For instance, the subsystem 220 may choose a super low modulation frequency (e.g., one bit in 40 seconds) and stepping up the modulation frequency overnight until no modulation depth can be found in the remote analyzer or detection apparatus 300 (as the peaks and valleys of the ionizer wave get smeared out by chaotic airflows).

FIG. 3 schematically depicts basic components of a remote ion analyzer or detection apparatus 300, which comprising detection means to measure ion concentration over time. The ion concentration detected by the analyzer or detection apparatus 300 is an overlaid effect of the modulated and/or un-modulated ion streams emitted by a plurality of ionizers 201, 202, 203 located in the area. The measurement result derived over time represents an average ionization level in the area, providing a real-time air quality indication. This can be a very interesting information for users, such as meeting participants in the room.

The remote ion analyzer or detection apparatus 300 is further configured to determine a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream. The individual contribution of a single modulated stream can be used to justify the operation performance of the ionizer emitting that stream. According to the determined contribution, an air ionization status of an air ionizer that generates the modulated stream can be identified. Therefore, although only one remote ion analyzer or detection apparatus 300 is deployed in the distributed ionization monitoring system 100, with the aid of coded modulation the performance of an individual ionizer out of a plurality of ionizers 201, 202, 203 can be evaluated.

The remote ion detection apparatus 300 may further comprise a user interface 310 to display information of the air ionization status and/or ion concentration. The user interface may be one or more signal lights, such as signal LEDs, and/or a small display on the remote ion detection apparatus 300. The measured ion concentration or average ionization level may be presented visually by the one or more signal lights. In one example, a simple traffic light indicator may be used to provide direct feedback on whether ion concentration is good or not for the users of the space, depending on if sufficient ions have recently reached the surface to ensure that it is disinfected. In another example, a text message, a graph, or a table may be displayed in the user interface 310 to provide more insights to the users about the ionization condition in the space.

Preferably, the remote ion detection apparatus 300 further comprises a radio 340 to send a feedback signal. The radio 340 comprises at least a transmitter for sending the

feedback signal according to a wireless communication protocol, such as Bluetooth, BLE, Zigbee, or Wi-Fi. The feedback signal may be formulated according to the measurement results obtained, such as the overlaid ion concentration, a unique signature detected, a list of unique signatures detected over a certain time window, ionization status identified of a modulated stream.

Such feedback signal may be sent to either an ion generation apparatus 220 or a remote controller, which may be a handheld user device, such as a mobile phone, to facilitate a feedback control loop for controlling the ionization system. Depending on if the feedback signal is related to a single ionizer or multiple ionizers, the ion generation apparatus 220 may adjust the control accordingly. When there is no feedback signal obtained for a certain ionizer for a certain period of time, a warning of mal function of that ionizer may be triggered.

The remote ion detection apparatus 300 may further comprise a sensor 350 to detect or sense other relevant parameters, such as a speed of air flow, occupancy information, room state information (window/door open/closed status, room temperature/humidity, a context parameter about the room). The additional information detected or sensed by the sensor 350 may be used to derive a more accurate estimation on the ion concentration or average ionization level of the space. Similarly, such additional information may also be used when identifying the air ionization status of a single air ionizer. In one example, the radio 340 is further configured to include the further parameter in the feedback signal to the ion generation apparatus 220 or the remote controller of a building automation or management system. And then, further analysis by considering an additional environmental or context parameter may be also carried out at the ion generation apparatus 220 side or the remote controller side.

FIG. 4(a) shows a flow chart of a method 500 of an air ion generating subsystem 220. The method 500 comprises the air ion generating subsystem 220: in step S501, generating and emitting a first stream of ionized air molecules via a first air ionizer, wherein the first stream is modulated using a unique signature of the first air ionizer; and in step S502, generating and emitting a second stream of ionized air molecules via a second air ionizer 202, wherein the second stream is modulated using a unique signature of the second air ionizer.

FIG. 4(b) shows a flow chart of an air ionization monitoring method 600 of a remote ion detection apparatus 300. The method 600 comprises the remote ion detection apparatus (300): measuring, in step S601, ion concentration over time; and in step S602,

determining a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.

The methods according to the invention may be implemented on a computer as a computer implemented method, or in dedicated hardware, or in a combination of both.

5 Executable code for a method according to the invention may be stored on computer/machine readable storage means. Examples of computer/machine readable storage means include non-volatile memory devices, optical storage medium/devices, solid-state media, integrated circuits, servers, etc. Preferably, the computer program product comprises non-transitory program code means stored on a computer readable medium for performing a
10 method according to the invention when said program product is executed on a computer.

Methods, systems, and computer-readable media (transitory and non-transitory) may also be provided to implement selected aspects of the above-described embodiments.

15 The terms “program” or “computer program” are used herein in a generic sense to refer to any type of computer code (e.g., software or microcode) that can be employed to program one or more processors or controllers.

CLAIMS:

1. A distributed ionization monitoring system (100) comprising:
 - a first air ionizer (201) configured to generate and emit a first stream of ionized air molecules, wherein the first air ionizer (201) is further configured to generate the first stream by modulating emission of ionized air molecules of the first stream with a
5 unique signature dedicated to the first air ionizer;
 - a second air ionizer (202) configured to generate and emit a second stream of ionized air molecules, wherein the second air ionizer (202) is further configured to generate the second stream by modulating emission of ionized air molecules of the second stream with a unique signature dedicated to the second air ionizer; wherein each of
10 the first air ionizer (201) and the second air ionizer (202) is configured to modulate the emission of ionized air molecules according to a different combination of modulation frequency, pulse slope and amplitude; and
 - a remote ion detection apparatus (300) configured to:
 - measure ion concentration over time;
 - 15 ○ determine a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.
2. The distributed ionization monitoring system (100) of claim 1, the remote ion
20 detection apparatus (300) is further configured to:
 - infer, according to the determined contribution, an air ionization status of an individual one out of the two air ionizers that generates the modulated stream.
3. The distributed ionization monitoring system (100) of claim 2 further
25 comprising:
 - a central controller;wherein the remote ion detection apparatus (300) is further configured to send the air ionization status to the central controller.

4. An air ion generating subsystem (220) comprising:

- a first air ionizer (201) configured to generate and emit a first stream of ionized air molecules, wherein the first air ionizer (201) is further configured to generate the first stream by modulating emission of the ionized air molecules of the first stream with a unique signature of the first air ionizer;
- a second air ionizer (202) configured to generate and emit a second stream of ionized air molecules, wherein the second air ionizer (202) is further configured to generate the second stream by modulating emission of ionized air molecules of the second stream with a unique signature of the second air ionizer;

wherein each of the first air ionizer (201) and the second air ionizer (202) is configured to modulate the emission of ionized air molecules according to a different combination of modulation frequency, pulse slope and amplitude.

5. The air ion generating subsystem (220) of claim 4, the air ion generating

subsystem (220) further comprising a processor (230), the processor (230) configured to:

- determine the unique signatures for controlling the first and the second air ionizers (201, 202);
- generate ion generation control signals based on a configuration parameter and the unique signatures; and
- control the first and the second air ionizers (201, 202) with the corresponding ion generation control signal.

6. The air ion generating subsystem (220) of claim 5, the configuration parameter

is related to at least one of: a selection between a modulated mode and an unmodulated

mode, a time schedule on using the modulated mode and the unmodulated mode, a first setting on a modulation frequency, a second setting on a pulse slope, and a third setting on an amplitude.

7. The air ion generating subsystem (220) of claim 5 or 6, the air ion generating

subsystem (220) further comprising a radio (240), the radio (240) configured to

- receive a feedback signal from a remote ion detection apparatus,

and the processor (230) further configured to

- adjust at least one of the ion generation control signals according to the feedback signal.

8. The air ion generating subsystem (220) of claim 7, wherein the feedback signal comprises information related to at least one of: a remotely detected air ionization status, a list of detected unique signatures, ion concentration, a type of ions, a speed of air flow of a predefined area, occupancy information of the predefined area, an activity in the predefined area, and room state information.

9. A remote ion detection apparatus (300) configured to:

- measure ion concentration over time;
- determine a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.

10. The remote ion detection apparatus (300) of claim 9, the remote ion detection apparatus (300) further configured to:

- identify, according to the determined contribution, an air ionization status of an air ionizer that generates the modulated stream.

11. The remote ion detection apparatus (300) of claim 10, the remote ion detection apparatus (300) further comprising a user interface (310) to display information of the air ionization status and/or ion concentration.

12. The remote ion detection apparatus (300) of any one of previous claims 9-11, the remote ion detection apparatus (300) further comprising a radio (340) to send a feedback signal, wherein the feedback signal is related to at least one of: identified ionization status, a unique signature detected, ion concentration, and a type of ions.

13. The remote ion detection apparatus (300) of any one of previous claims 9-12, the remote ion detection apparatus (300) further comprising a sensor (350) to detect a further parameter related to a predefined area, and wherein the further parameter is related to at least one of: a speed of air flow within the predefined area, occupancy information of the predefined area, an activity in the predefined area, and room state information; and the remote ion detection apparatus (300) further configured to take the further parameter into consideration when identifying the air ionization status of the air ionizer.

14. The remote ion detection apparatus (300) of claim 13, wherein the radio (340) is further configured to include the further parameter in the feedback signal.

5 15. A method (500) of an air ion generating subsystem (220), the method comprising the air ion generating subsystem (220):

- generating and emitting (S501) a first stream of ionized air molecules via a first air ionizer (201), wherein the first stream is generated by modulating emission of the ionized air molecules with a unique signature dedicated to the first air ionizer;
- 10 - generating and emitting (S502) a second stream of ionized air molecules via a second air ionizer (202), wherein the second stream is generated by modulating emission of the ionized air molecules with a unique signature dedicated to the second air ionizer; wherein the modulation is implemented according to a different combination of modulation frequency, pulse slope and amplitude.

15 16. An air ionization monitoring method (600) of a remote ion detection apparatus (300), the method comprising remote ion detection apparatus (300):

- measuring (S601) ion concentration over time;
- determining (S602) a contribution from a modulated stream of ionized air molecules to the measured ion concentration by detecting a unique signature embedded in the modulated stream.

17. A computing program comprising code means which, when the program is executed by:

- 25 - an air ion generating subsystem (220) according to any one of claims 4-8 to cause the air ion generating apparatus subsystem (220) to execute the steps of the method of claim 15 or
- a remote ion detection apparatus (300) according to any one of claims 9-14 to cause the remote ion detection apparatus (300) to execute the steps of the method of claim
- 30 16.

1/2

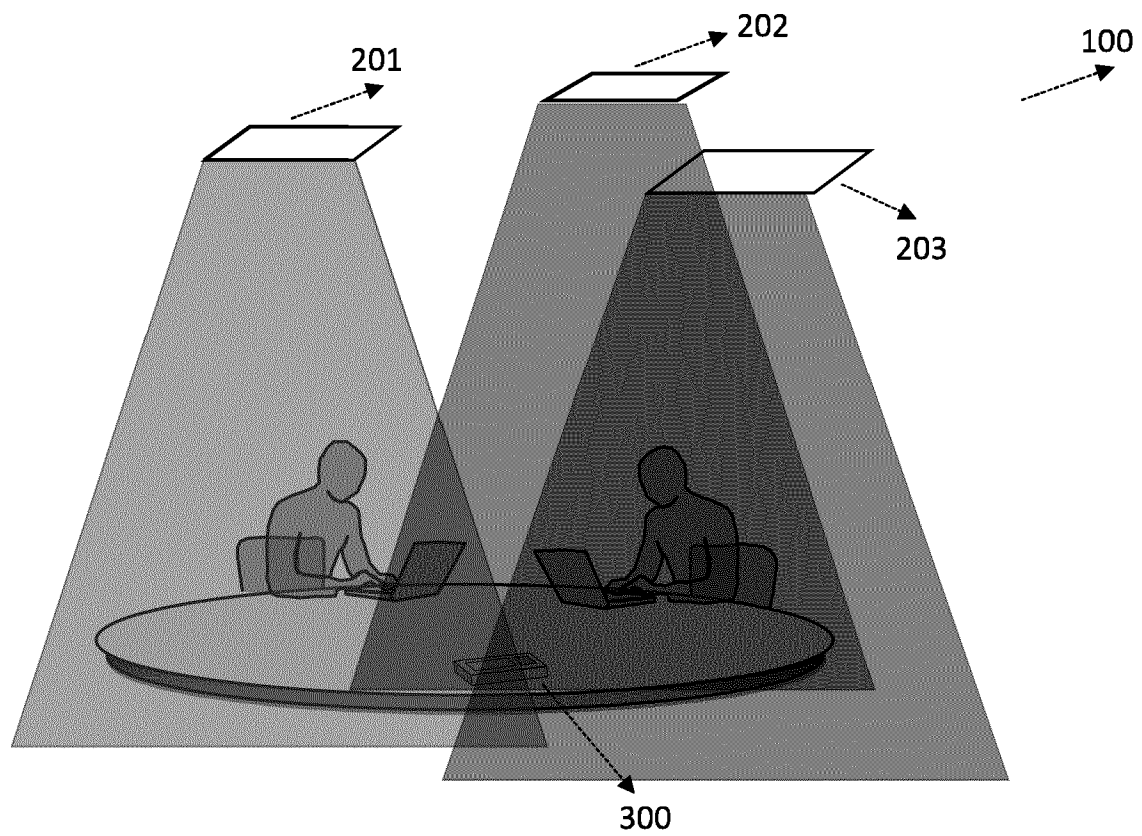


FIG. 1

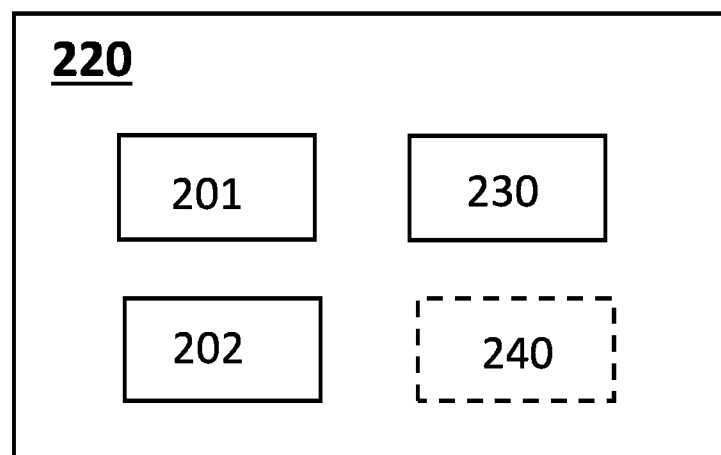


FIG. 2

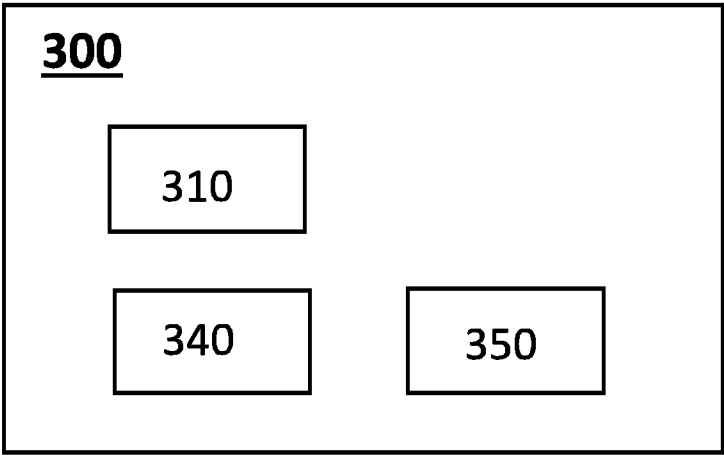
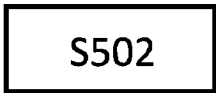
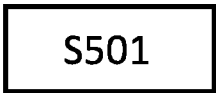


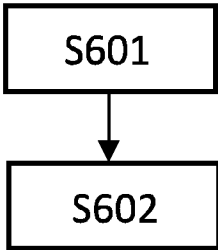
FIG. 3

500



(a)

600



(b)

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/053522

A. CLASSIFICATION OF SUBJECT MATTER INV. F24F8/30 F24F11/52 F24F11/65 F24F11/70 H01T19/00 H01T23/00 H05F3/06 ADD. F24F110/30 F24F120/10 F24F120/14		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F24F H05C H01T H05F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 2 May 2022		Date of mailing of the international search report 11/05/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Blot, Pierre-Edouard

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International application No

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