

A SYSTEM AND A METHOD FOR REDUCING PARTICULATE POLLUTANTS IN AIR, USING PULSED ELECTROMAGNETIC WAVES

FIELD OF INVENTION

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[01] The present disclosure relates to the field of reducing particulate pollutants in air. In particular, it belongs to the field of use of electromagnetic radiation for reducing particulate pollutants in air.

BACKGROUND OF THE INVENTION

10 [02] Air pollution affects 92% of the world's population and is estimated to causes 7 million premature deaths annually. It is also estimated that it costs developing countries 8.5% of their Gross Domestic Product. Poor air quality is a matter of great concern in
15 developing countries. Particulate matter has long been recognized as one of the key pollutants detrimental to human health (Harrison and Yin, 2000; Leiva G *et al.*, 2013; Martinelli, Olivieri and Girelli, 2013).

[03] There is compelling evidence of the adverse effects of particulate matter on
20 public health at exposure levels as experienced by global urban populations (World Health Organization, 2005). A recent survey by the National Clean Air Program initiative identified 102 non-attainment cities in India, which fail to meet the National ambient air quality standards. Conventional pollution management strategies to improve air quality include promoting green energy efficient fuels as alternatives to fossil fuels.
25 Efforts also include the use of green transportation systems. Use of Electrostatic precipitators, scrubbers, filters for industrial establishments are mandated by law and efforts towards improved enforcement of compliance in industries are under way.

[04] Despite these measures, air pollution continues to increase. Although there are
30 several air pollution control devices in the market, most of them are associated with high initial capital cost, high operation and maintenance cost and low area of coverage.

[05] Conventionally, there are two types of air purifying technologies available - active and passive. Active air purifiers release negatively charged ions into the air, causing pollutants to stick to surfaces, while passive air purification units use air filters to remove pollutants.

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[06] The most common types of air purifier technologies are listed below:

- HEPA Technology
- Activated Carbon Technology
- Electrostatic precipitator
- Negative Ion
- Ozone

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[07] The main features of each of these technologies along with their major advantages and disadvantages are shown in the table in **Figure 1**.

15 [08] High Efficiency Particulate Air (HEPA) technology uses filters that must meet predefined standards. Large particles are unable to pass through the openings of the fibers and are caught. The smaller particles get caught by one of three mechanisms – interception, impaction and diffusion. HEPA air purifiers are the most effective at trapping airborne particles.

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[09] Activated Carbon Technology uses a form of carbon that has been processed to make it extremely porous and to give it a very large surface area for absorption and adsorption. Air purifiers with activated carbon filters are particularly helpful to people with Multiple Chemical Sensitivity (MCS) because they absorb formaldehyde, which is
25 found in carpet, wood paneling, and furniture upholstery. Activated Carbon air filters help in reducing the contamination of the air. They do, however, have a low efficiency in removing allergens and airborne particles. They also act in closed spaces and with limited range.

[010] Electrostatic precipitator also called electrostatic air cleaner is a device that uses a high-intensity electric field to remove certain impurities - solid particles and liquid droplets from air or gases in smokestacks and flues. Originally configured for recovery of valuable industrial process materials, electrostatic precipitators are used for air pollution control. Dust particles, once collected, are removed from the collector plates periodically. Electrostatic precipitators are efficient in removing particulate pollutants and can be used to collect dry as well as wet pollutants at low operating costs in industrial smokestacks. However, electrostatic precipitators have a high initial capital cost. They require large spaces for installation and once installed they are not flexible in operation.

[011] Negative Ion air purifiers use chemical injections to clean the air. An ion is a particle with either a positive or negative charge. Negative ions are simply atoms that have gained an electron. They attract airborne particles such as pollen and dust, until the newly formed particles are too heavy to remain suspended in air. This causes the particle to drop and settle, leaving the air cleaner.

[012] Ozone air purifiers produce ozone (O_3) which reacts with strong odors and airborne chemicals. Although it is believed that these devices are safe and effective in controlling indoor air pollution, governments have not approved these devices, because it may cause breathing difficulties in some people and may also be carcinogenic. Further, Ozone itself is considered to be a pollutant.

[013] All these device and methods are useful in a limited area or in enclosed spaces.

SUMMARY OF THE INVENTION

[014] This summary is provided to introduce a selection of concepts in a simple manner that is further described in the detailed description of the disclosure. This summary is not intended to identify key or essential inventive concepts of the subject matter nor is it intended for determining the scope of the disclosure.

[015] Thus, there is no method or system available that can reduce particulate pollutants across a large area. Thus, there has been a long felt need for a method of purifying air of particulate matter and gaseous pollutants and an air purifier device that
5 clears the ambient air of suspended particles or particulate pollutants.

[016] This disclosure discloses a method of purifying air that can overcome at least one of the disadvantages of the state of the art methods in purifying air of particulate matter and also some gaseous pollutants.

10 [017] This disclosure discloses an air purifier system that can overcome at least one of the disadvantages of the state of the art systems in purifying air of particulate matter contained in it and also some gaseous pollutants.

15 [018] The disclosed method comprises radiating pulsed electromagnetic radiation in the radiofrequency band for accelerating the agglomeration of particulate matter in the air such that they settle down as aggregates and thereby reduce the percentage of particulate matter in the air. The interaction of suspended particulate matter of size less than 10 μm with the radio waves causes them to agglomerate, become heavier and
20 hence their precipitation is speeded up. Thus the suspended particulate matter settles down faster than they would otherwise do. The clearance or transport of particles from the air to the solid surfaces in the absence of precipitation occurs by the natural phenomenon of Dry deposition. Further, the method is effective in operation over a large area surrounding the system - up to a radius of 1 to 3 kilometers.

25 [019] Also disclosed is a device for radiating pulsed electromagnetic radiation in the radiofrequency band, with a predefined nominal frequency for promoting the agglomeration of particulate matter in the air such that they settle down as a precipitate and thereby reduce the percentage of particulate matter in the air.

30 [020] This disclosure further discloses a system, comprising the disclosed device whereby the purification of air can be managed effectively.

[021] The disclosed system is configured for radiating radio waves, preferably in the frequency range of 800 MHz to 5 GHz in a predefined pulsed manner. Essentially the disclosed system comprises the device comprising a radiofrequency oscillator tuned to
5 or otherwise configured for oscillating at the predefined frequency. The signal is then suitably power amplified and using a suitable switch the amplified output is routed to a radiating antenna. In one embodiment there are two antennae, one polarizing omnidirectional antenna and a directional antenna. The omnidirectional antenna is used for all round coverage to induce agglomeration of particulate matter all around the
10 system. The directional antenna is used when the source of the pollution is known and the emission of particulate matter is to be controlled at the source, to prevent it from spreading to a larger area. The power amplified signal is pulsed with variations in echo train length (5 to 200), duty cycle (10% to 80%), and pulse power amplitude (20% to 100% of max power).

15 [022] Further to clarify the advantages and features of the present disclosure, a more particular description of the disclosure will be rendered by reference to specific embodiments thereof, which is illustrated in the appended figures. It is to be appreciated that these figures depict only typical embodiments of the disclosure and are therefore
20 not to be considered limiting of its scope. The disclosed method, device, and system will be described and explained with additional specificity and detail with the accompanying figures.

BRIEF DESCRIPTION OF FIGURES

25 [023] The disclosure will be described and explained with additional specificity and detail with the accompanying figures in which:

[024] **Figure 1** shows a table comparing the prior art methods for preventing or
30 reducing ambient or/and indoor pollution;

[025] Figure 2 is a block diagram of a system for reducing particulate pollutants in air in accordance with an embodiment of the present disclosure; and

[026] Figure 3 is a detailed block diagram of the device 215 for generating and radiating the pulsed electromagnetic waves for reducing the particulate pollutants in air in accordance with an embodiment of the present disclosure.

[027] Further, persons skilled in the art to which this disclosure belongs will appreciate that elements in the figures are illustrated for simplicity and may not have been necessarily drawn to scale. Furthermore, in terms of the construction of the joining ring and one or more components of the bearing assembly may have been represented in the figures by conventional symbols, and the figures may show only those specific details that are pertinent to understanding the embodiments of the present disclosure so as not to obscure the figures with details that will be readily apparent to those of ordinary skill in the art having benefit of the description herein.

DETAILED DESCRIPTION

[028] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the embodiment illustrated in the figures and specific language will be used to describe them. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Such alterations and further modifications to the disclosure, and such further applications of the principles of the disclosure as described herein being contemplated as would normally occur to one skilled in the art to which the disclosure relates are deemed to be a part of this disclosure.

[029] It will be understood by those skilled in the art that the foregoing general description and the following detailed description are exemplary and explanatory of the disclosure and are not intended to be restrictive thereof.

[030] In the present disclosure, relational terms such as first and second, and the like, may be used to distinguish one entity from the other, without necessarily implying any actual relationship or order between such entities.

5 [031] The terms "comprises", "comprising", or any other variations thereof, are intended to cover a non-exclusive inclusion, such that a process or method that comprises a list of steps does not include only those steps but may include other steps not expressly listed or inherent to such a process or a method. Similarly, one or more elements or structures or components preceded by "comprises... a" does not, without
10 more constraints, preclude the existence of other elements, other structures, other components, additional devices, additional elements, additional structures, or additional components. Appearances of the phrase "in an embodiment", "in another embodiment" and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

15 [032] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. The components, methods, and examples provided herein are illustrative only and not intended to be limiting.

20 [033] While aspects of proposed disclosure may be implemented in any number of different computing systems, environments, and/or configurations, the embodiments are described in the context of the following exemplary environment.

25 [034] Figure 2 is a block diagram of a system for reducing particulate pollutants in air in accordance with an embodiment of the present disclosure. As shown, the system 200 comprises a server 205, a communication network 210 and a device for generating pulsed electromagnetic waves 215 (hereinafter referred to as device 215), wherein the device 215 comprises a control module 220, a power supply module 225, an RF
30 transmitter 230, an RF switch 235 and two antennae 240 and 245.

[035] The server 205 may include, for example, a computer server or a network of computers or a virtual server comprising one or more processors, associated processing modules, interfaces and storage devices. As shown, the server 205 is communicatively connected to the device 215 through the communication network 210. In one
5 embodiment of the present disclosure, the server 205 is configured for communicating operating instructions to the device 215 for operating the device 215 depending on one or more factors. The one or more factors may include, but not limited to, a geographical location of the device 215, a current atmospheric condition, that is, the ambient temperature and relative humidity or both, at the geographical location of the device
10 215, an estimate of the pollution characteristics at the geographical location and one or more inputs provided by a user of the device 215. In other words, the server 205 enables remote operation of the device 215 for reducing the air pollution. Further, the server 205 is configured for monitoring the state of health of the device 215. It is to be noted that the server 205 may be communicatively connected with a plurality of devices, each
15 being of the type similar to the device 215, for controlling the air pollution using various devices at the same or different geographical locations and for monitoring the health of the plurality of devices.

[036] The communication network 210 may be a wireless network or a wired network or a combination thereof. Wireless network may include long range wireless radio,
20 wireless personal area network (WPAN), wireless local area network (WLAN), mobile data communications such as 3G, 4G or any other similar technologies. The communication network 210 may be implemented as one of the different types of networks, such as intranet, local area network (LAN), wide area network (WAN), the internet, and the like. The communication network 210 may either be a dedicated
25 network or a shared network. The shared network represents an association of the different types of networks that use a variety of protocols, for example, Hypertext Transfer Protocol (HTTP), Transmission Control Protocol/Internet Protocol (TCP/IP), Wireless Application Protocol (WAP), and the like. Further the communication network 210 may include a variety of network devices, including routers, bridges, servers,
30 modems, computing devices, storage devices, and the like. In one implementation, the

communication network **210** is the internet which enables communication between the server **205** and the device **215** which generates the pulsed electromagnetic waves **215**.

[037] In one embodiment of the present disclosure, the device **215** is configured for
5 generating pulsed electromagnetic waves in the frequency range of 2.4 to 2.5 GHz (ISM Band) and the generated pulsed electromagnetic waves are radiated using a unidirectional antenna or an omnidirectional antenna or both. The electromagnetic waves are pulsed with variations in echo train length, duty cycle, and pulse amplitude according to the local conditions, that is, the ambient temperature and relative humidity
10 or both of the geographical area. The radiated pulsed electromagnetic waves create dielectric effect under the influence of a spatially non-uniform electric field. As a result, the small pollutant particles undergo a net translational motion via the dielectrophoretic force, causing their motion to accelerate, and the pollutant particles in the air settle down as a result of aggregation of the pollutant particles, thereby reducing their
15 concentrations in the air. The manner in which the pulsed electromagnetic waves are generated and radiated for reducing the particulate pollutants in air is described in detail further below.

[038] Figure 3 is a detailed block diagram of the device **215** for generating and
20 radiating the pulsed electromagnetic waves for reducing the particulate pollutants in air in accordance with an embodiment of the present disclosure. As shown and described with reference to Figure 2, the device **215** comprises the control module **220**, power supply module **225**, the RF transmitter **230**, the RF switch **235** and two antennae **240** and **245**. Further, in one embodiment of the present disclosure, the RF module **230**
25 comprises a signal generator **305**, an RF amplifier **310** and a reference oscillator **315**. Functions of said modules in generating the pulsed electromagnetic waves are described in detail further below.

[039] The control module **220** includes a microcontroller for controlling the various
30 operations of the device **215**. In one implementation, the control module **220** is 8-bit microcontroller operating with an internal clock of 32 MHz (Programmable). The

control module **220** controls an Ethernet controller **320**, the signal generator **305** (RF Synthesizer), the RF Amplifier **310** and the RF switch **235**. The communication between control module **220** (microcontroller) and the Ethernet controller **320** is through SPI Protocol. One end of the Ethernet controller **320** is connected to the control module **220** and the other end is connected to RJ 45 Connector. The control module **220** receives remote control data via communication modem and through the Ethernet controller **320**. In one implementation, the control module **220** and the signal generator **305** communicate through SPI protocol. In one embodiment of the present disclosure, the control module **220** is used to program the signal generator **305** for proper output frequency, duty cycle and output power. The output power of the signal generator **305** may be varied by steps of 3 dB. The Ethernet controller **320** can communicate with 2G/3G/LTE and Ethernet supported modem, there by establishing internet access. The control module **220** ensures remote monitoring as well as control and variation of the RF pulse parameters.

[040] The power supply module **225** is mediated through an adapter with AC Input at 90 ~ 264 VAC, 50/60 Hz and DC Output at 12 V, 2 A, 24 W. The supply voltages of all ICs in the device are either 3.3V or 5V. In one implementation DC to DC converters or regulators are used to step down the voltage from adapter into two levels. The maximum current drawn by each regulator is 1 A. Both the regulators receive 12 V from the AC to DC adapter. The DC to DC converters converts the DC voltage to 3.3 V and 5 V. For adequate power dissipation, proper heat sink selection and the copper area under the module is in place. Additionally, provided is an EMI filter circuit of DC to DC converter to effectively reduce EMI noise for both conducted and radiated test by filtering the input voltage. The power supply module **225** supplies DC operating voltages to all the modules of the device **215**.

[041] As described, the device **215** generates the pulsed electromagnetic waves in the frequency range of 800 MHz to 5 GHz and the generated pulsed electromagnetic waves are radiated using one of the unidirectional antenna and the omnidirectional antenna. In particular, the signal generator **305** generates the signal with the desired frequency from

a reference input from the reference oscillator **315**, the generated signal is amplified using the RF amplifier **310**, the amplified signal is periodically interrupted for generating the pulsed signal (pulsed electromagnetic waves), and the pulsed electromagnetic waves are radiated through one of the antenna **240** and **245**, selected using the RF switch **235**, into the air. The pulsed electromagnetic waves accelerate the agglomeration of particulate matter suspended in the air thereby accelerating the precipitation of the particulate matter, and thereby reducing the proportion of particulate matter suspended in the air. It is to be noted that the pulsed electromagnetic waves may be generated in one or more methods. As described, in one implementation, the signal is generated using the signal generator **305**, the signal is amplified using the RF amplifier **310**, and the amplified signal is interrupted before feeding it to the antenna for generating the pulsed signals (pulsed electromagnetic waves). In another implementation, the signal is generated using the signal generator **305**, the generated signal is interrupted before feeding it to the RF amplifier **310** for generating the pulsed signal, and the pulsed signal is amplified and fed to the antenna. A pulse width modulator **325** for interrupting the signal is shown in **Figure 3**. In yet another implementation, a pulsed signal is generated using the signal generator **305**, and then the pulsed signal is power amplified and fed to the antenna. It is to be noted that the signal generator **305** and the RF amplifier **310** are digitally controlled to attain the required power and the duty cycle. As described, any one of the method may be implemented for generating the pulsed electromagnetic waves. The pulse width modulator **325** is shown in **Figure 3** for illustrating one of the methods.

[042] Referring back to **Figure 3**, in one embodiment of the present disclosure, the signal generator **305** is configured for generating a signal in the frequency range of 800 MHz to 5 GHz from a single reference frequency from the reference oscillator **315**. That is, the signal generator **305** receives RF reference input from the RF oscillator **315** and produces an output. The minimum RF output power is -4 dBm and maximum is +5 dBm. The output frequency is programmable in the RF synthesizer **305** and the output is fed to the RF amplifier **310**.

[043] As described, the reference oscillator **315** inputs a reference frequency to the signal generator **305** for generating signal of 800 MHz to 5 GHz. In one implementation, 25 MHz temperature compensated crystal oscillator is used for generating 25 MHz reference signal. In the present case the reference oscillator **315** is selected to have the preferred frequency of 25 MHz with a piezo electric or any other suitable reference.

[044] In one embodiment of the present disclosure, the RF amplifier **310** is a variable gain RF amplifier which receives the signal from the signal generator **305** and controls the output power from the signal generator **305**. The output of the RF amplifier **310** is connected to the RF switch **235**.

[045] In one embodiment of the present disclosure, the RF switch **235** is used for selecting one of an omnidirectional antenna **240** or a directional antenna **245** for radiating the pulsed electromagnetic radiation into the atmosphere. In a preferred embodiment, the RF switch **235** is a digitally controlled single pole double throw switch configured for taking input from RF amplifier **310**. The output RF1 or RF2 is selected, for radiating electromagnetic radiation through an omnidirectional antenna **240** or a directional antenna **245**, through the logic control voltages from control module **220**. The RF switch **235** provides desired isolation between the two RF paths.

[046] The antennae **240** and **245** are broad range omnidirectional and directional antennae for radiating pulsed electromagnetic waves into the atmosphere. The omnidirectional antenna **240** is used for all round coverage to induce agglomeration of the particulate matter all around the antenna **240**. The directional antenna **245** is used when the source of the pollution is known and the emission of particulate matters is to be controlled at the source, to prevent particulate matters from spreading to a larger area. Based on the application, one of the antennae **240** and **245** are selected through the RF switch **235** through the control module **220**.

Working Mechanism:

[047] The control module **220** of the device **215** controls the RF signal generator **305**, the RF switch **235** and digital step attenuator in the variable gain RF amplifier **310**. The reference oscillator **315** provides the reference frequency required for the RF signal generator **305**. Based on the reference signal and the control from the control module **220**, the RF signal generator **305** produce an output in four different levels (between -4 dBm and 5 dBm) at a frequency of 800 MHz to 5 GHz (programmable as per the local conditions). This RF signal is amplified to levels that can be digitally controlled using control module **220** (by controlling attenuation of digital step attenuator) by the variable gain RF amplifier **310**. The output power of the variable gain RF amplifier **310** drives the externally connected antennae. The antennae are connected through single pole double throw switch **235** which is controlled by the control module **220**. Using internet access, the device **215** can also be accessed remotely through the server **205** and the communication network **210** to select the of antenna and pulse modulation parameters.

[048] During operation, one of the antennae **240** and **245** radiates the pulsed electromagnetic waves into the atmosphere. The radiated pulsed electromagnetic waves create dielectric effect under the influence of a spatially non-uniform electric field. As a result, the small pollutant particles undergo a net translational motion via the dielectrophoretic force, causing their motion to accelerate, and the pollutant particles in the air settles down as a result of agglomeration of the pollutant particles, thereby reducing the air pollution.

[049] The use of pulsed electromagnetic waves in the Wi-Fi® frequency range reduces the levels of particle pollutants in ambient and indoor air spaces to mitigate air pollution. The pulsed radio wave technology reduces particulate pollutants (PM2.5 and PM10) by a minimum of 33% and 50 - 60% in most of cases. Certain gaseous pollutants (typically as aerosols or secondary particulate pollutants) such as nitrogen oxides, Sulphur dioxide, and carbon monoxide are reduced by 20-30% depending on their initial concentration. Unlike conventional air purifiers which make use of HEPA filters,

pulsed radio wave technology uses an omnidirectional antenna or a directional antenna to generate weak radio waves in a specific pulsed sequence. Because radio waves are able to travel over long distances (compared to cell phone signals, Bluetooth, or Wi-Fi), the technology is able to work over large distances. The pulsed radio waves accelerate
5 the velocity of the small particle pollutants (< 20 microns) and aerosols, increasing their clearance through a natural process called dry deposition.

[050] The system and device disclosed in the disclosure for reducing particulate pollutants in air, using pulsed electromagnetic waves, doesn't require fans or filters and
10 hence sustainable with low recurring cost in comparison with convention air purifier or air pollution control systems. Further, the device covers larger area as the pulsed radio waves cover an average of 1000-2000 m radius, which is at least ten times more than the conventional purifiers. Furthermore, the device utilizes minimum power of 30W, and doesn't produce noise.

15 [051] While specific language has been used to describe the disclosure, any limitations arising on account of the same are not intended. As would be apparent to a person skilled in the art, various working modifications may be made to the method in order to implement the inventive concept as taught herein.

20 [052] The figures and the foregoing description give examples of embodiments. Those skilled in the art will appreciate that one or more of the described elements may well be combined into a single functional element. Alternatively, certain elements may be split into multiple functional elements. Elements from one embodiment may be added to
25 another embodiment. For example, orders of processes described herein may be changed and are not limited to the manner described herein. Moreover, the actions of any flow diagram need not be implemented in the order shown; nor do all of the acts necessarily need to be performed. Also, those acts that are not dependent on other acts may be performed in parallel with the other acts. The scope of embodiments is by no
30 means limited by these specific examples. Numerous variations, whether explicitly given in the specification or not, such as differences in structure, dimension, and use of

material, are possible. The scope of embodiments is at least as broad as given by the following claims.