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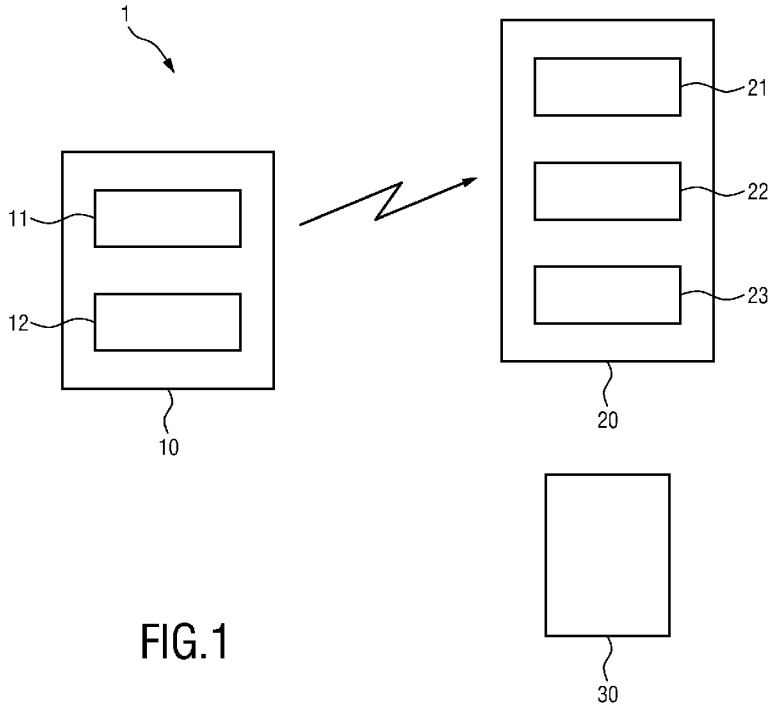


FIG.1

(57) Abstract: The present invention relates to a wireless transmitter for use in a wireless system, a wireless transmission method, an electronic device for use in a wireless system, a wireless reception method and a wireless system. To increase efficiency of use of energy and/or applicability, the wireless transmitter comprises a transmission unit (11) for wirelessly transmitting signals to an electronic device comprising a wireless receiver, and a signal construction unit (12) for constructing signals for transmission, said signals including powering burst signals and message signals, a powering burst signal being configured to provide electrical power to the electronic device for powering the electronic device, wherein said signal construction unit (12) is further configured to construct a powering burst signal as required to enable the electronic device to receive a message signal and perform a task and said transmission unit (11) is configured to transmit, in advance of transmitting the message signal, the constructed powering burst signal.

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Wireless transmitter and electronic device for use in a wireless system

FIELD OF THE INVENTION

The present invention relates to a wireless transmitter for use in a wireless system, a wireless transmission method, an electronic device for use in a wireless system, a wireless reception method and a wireless system.

BACKGROUND OF THE INVENTION

The paper Vamsi Talla, Bryce Kellogg, Benjamin Ransford, Saman Naderiparizi, Shyamnath Gollakota and Joshua R. Smith: "Powering the Next Billion Devices with Wi-Fi", University of Washington, 25 May 2015, arXiv:1505.06815 describes how to achieve power over WiFi to charge IoT (Internet of Things) devices or, more generally, electronic devices. The paper describes a power over WiFi system that delivers power and works with existing WiFi chipsets. Specifically, it is shown that a ubiquitous piece of wireless communication infrastructure, the WiFi router, can provide far field wireless power without compromising the network's communication performance. Battery-free temperature and camera sensors are prototyped that are powered using WiFi chipsets with ranges of 20 and 17 feet respectively. Further, the ability to wirelessly recharge nickel-metal hydride and lithium-ion coin-cell batteries at distances of up to 28 feet is described.

The authors of the above cited paper further observe that the connection of a WiFi antenna to a harvester does not manage to achieve the required output to actually power a device, due to (i) discontinuous WiFi transmissions, providing only bursts of energy and (ii) leak currents, causing continuous drop in the energy. Therefore, the authors propose a system in which the router introduces additional broadcast traffic in different WiFi channels in such a way that one channel is active almost at any time (95%), and that the antenna and harvester have such a design that they can collect power over the whole WiFi spectrum. This means that the impedance coupling between antenna and harvester needs to be suitable over the whole frequency spectrum. With such a system, a router transmitting at +23 dBm can power exemplary WiFi sensor applications located at up to 28 feet in US indoor environment.

US 2015/0303741 A1 discloses an energy transmitting device (e.g., access point) that can transmit an energy signal to a wireless device. The wireless device can obtain

energy from the energy signal. The energy signal may be transmitted via an unused frequency sub-range of a frequency range associated with a communication signal. In one embodiment, the energy signal may occupy a frequency sub-range in unused frequencies of an orthogonal frequency division multiplexed (OFDM) signal transmission. The energy signal may be transmitted in a manner that coexists without interfering with traditional communication signals. Various control/configuration settings may be used to enable or disable the energy signal, for example, based on capability of a wireless device to harvest energy from the energy signal or in accordance with a schedule.

WO 2006/058309 A2 discloses a remote charging system including a power transmission unit, which transmits a wireless energy signal as a plurality of constructive transmitted frequencies, and a power receiver unit that receives the transmitted frequencies. The power receiver unit is preferably incorporated in a device and includes an energy receptor capable of receiving the wireless transmitted energy signal and transferring the energy from the transmitted frequencies to an energy storage device included in the device.

US 2013/121176 A1 discloses an energy-harvesting communication device of a communication network that accumulates energy, e.g., electromagnetic energy. Upon detecting that the accumulated energy surpasses a sufficient threshold, the communication device may transmit a message into the communication network using the accumulated energy as an unreliable and unsynchronized broadcast transmission to any available receiver within the communication network.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a wireless transmitter for use in a wireless system, a wireless transmission method, an electronic device for use in a wireless system, a wireless reception method and a wireless system, which are improved compared to the known components as described in the above cited paper, particularly with respect to efficiency of use of energy and/or with respect to applicability.

In a first aspect of the present invention a wireless transmitter for use in a wireless system is presented, said wireless transmitter comprising:

- a transmission unit for wirelessly transmitting signals to an electronic device comprising a wireless receiver, and
- a signal construction unit for constructing signals for transmission, said signals including powering burst signals and message signals, a powering burst signal being

configured to provide electrical power to the electronic device for powering the electronic device,

wherein said signal construction unit is further configured to construct a powering burst signal as required to enable the electronic device to receive a message signal and perform a task and said transmission unit is configured to transmit, in advance of transmitting the message signal, the constructed powering burst signal.

In a further aspect of the present invention an electronic device for use in a wireless system is presented, said electronic device comprising:

- a wireless receiver for wirelessly receiving signals transmitted by a wireless transmitter, said signals including powering burst signals and message signals,
- a power extraction unit for extracting power from a powering burst signal being configured to provide electrical power to the electronic device for powering the electronic device, a powering burst signal being constructed as required to enable the electronic device to receive a message signal and perform a task and the constructed powering burst signal being transmitted, in advance of the message signal, and
- a task execution unit for performing the desired task using the extracted power.

In a further embodiment of the present invention a wireless system is presented comprising one or more wireless transmitters as disclosed herein and one or more electronic devices disclosed herein.

In yet further aspects of the present invention, there are provided a corresponding transmission method and a corresponding reception method.

Preferred embodiments of the invention are defined in the dependent claims. It shall be understood that the claimed methods, devices and system have similar and/or identical preferred embodiments as the claimed entities, in particular as defined in the dependent claims and as disclosed herein.

The method described in the above cited paper is conceptually meant for constant powering which can be very power hungry in extended spaces.The present invention is based on the idea to provide improved devices, methods and systems that are only supplying the electronic devices e.g. to IoT nodes, with power when required. One idea is basically to have a power burst signal (sometimes also called preamble) prior to the actual message, the power burst signal having enough energy to power the electronic device. In this way the electronic devices get only powered whenever messages are going out to the electronic devices. Thus, a message transmitted to an electronic device powered over WiFi is

thus preceded by a power burst signal (or extended preamble). The power burst signal may beoptimized for highest possible power transfer and does not contain payload data.

According to the present invention the powering burst signal is thus tweaked to the requirement that the electronic device shall be able to receive a transmitted message and perform a desired task. Generally, the amount of energy transmitted by the powering burst signal is thus limited to the necessary amount only to achieve an effiecient use of energy and avoid unnecessary electromagnetic radiation (due to too energy transmitted by the powering burst signal). The powering burst signal can thus be adapted to the kind of message to be transmitted (e.g. its length) and the desired task to be performed by the electronic device (e.g. sense a value, read out its status, send a response, etc.). Further, for adapting the powering burst signal the configuration and parameters of the electronic device and/or the wireless transmitter may be taken into account. For instance, the duration, amplitude, frequency, duty cycle and/or other parameters of the powering burst signal may be controlled to construct the powering burst signal accordingly.

According to a preferred embodiment said transmission unit is configured to transmit said powering burst signal with maximum transmission power. Typically, access points (i.e. wireless transmitters) do control the amplitude of transmission in relation to the information (and signal strength) they receive from communication devices (i.e. wireless receivers). In order to keep the channel occupation in the powering burst signals short it is preferred to use the full available signal strength. Hence, the automatic transmission amplitude adaptation is preferably deactivated to send the most powerful signal the transmission unit is able to provide. Notably the most powerful signal generally qualifies as being a predetermined maximum transmit power, which predetermined maximum transmit power could be on the physical device limitations, or could be a predetermined maximum transmit power as configured, for example in order to satisfy regulatory requirements.

According to a further embodiment said signal construction unit is configured to optimize said powering burst signal, in particular the signal sequence, the duration and/or information content of said powering burst signal, to enable a wireless receiver to extract as much electrical power as possible from said powering burst. For instance, the wireless transmitter may try different packet content and ask the wireless receiver which gives best harvesting performance. This may be done at the manufacturing site just to have a good starting point. Different fixed packets may be used to select from these. Further, this may also be optimized for an access point after installation (triggered by a manually operated push button or at power up or by means of a control massage). It may also be done each night just

to make sure powering burst signal packets are used that give a good harvest for all harvesting nodes (i.e. electronic devices) within reach.

Another parameter that might be mentioned but gets complex in a real application is the beam direction. Beam direction forming by means of multiple antennas and transmitters may be used by the wireless transmitter. According to an embodiment the beam width is kept as broad as possible as long as the best beam direction to an electronic device is not known by the wireless transmitter.

In another embodiment the signal construction unit is configured to construct and said transmission unit is configured to transmit a powering burst signal upon request from a user or from the electronic device. For instance, if the user wishes to make use of a particular electronic device, it may control the wireless transmitter to transmit a powering burst signal. In other embodiments the electronic device may issue a request to transmit a powering burst signal, e.g. if the electronic device realizes that its power storage is getting empty or at regular intervals.

Said signal construction unit may be configured to construct said powering burst signal according to a power request signal received from an electronic device indicating the power requirement of the an electronic device to perform a desired task. In this way the powering burst signal can be optimized and specifically adapted to the needs of the requesting electronic device.

In another embodiment said signal construction unit is configured to construct and said transmission unit is configured to transmit a polling signal for polling an electronic device. Thus, if the wireless transmitter seeks to communicate with an electronic device or wishes an electronic device to perform a task, it can poll the electronic device, in which way the electronic device may be woken up. Afterwards, the wireless transmitter can transmit the powering burst signal to enable the electronic device to obtain sufficient energy to perform the task.

The wireless transmitter may further comprise a memory for storing one or more transmission parameters of different electronic devices, said one or more transmission parameters including one or more of the power requirements to perform a desired task, the power storage capacity, the power harvesting method, the preferred transmission frequency, the preferred receive direction, wherein said signal construction unit is configured to construct the powering burst signal to be transmitted to a particular electronic device according to the stored one or more transmission parameters of said electronic device. Thus,

the powering burst signal can be optimized and specifically adapted to the needs of the electronic device.

The wireless transmitter may further comprise a reception unit for receiving a response signal from an electronic device and for analyzing one or more parameters of said response signal, in particular the length, bandwidth, frequency, content and/or strength of the response signal, wherein said signal construction unit is configured to construct the powering burst signal and/or said transmission unit is configured to adapt one or more transmission parameter dependent on the result of said analysis. This provides another way to optimize the powering burst signal and to specifically adapt it to the needs of the electronic device.

Said transmission unit may further be configured to synchronize transmission of said powering burst signal with the transmission of a powering burst signal by one or more further transmission units of the wireless system. In this way the transmission of power to one or more electronic devices by multiple transmission units can be coordinated and optimized. For instance, the transmission of power to a single electronic device can be accelerated.

The power extraction unit of the electronic device for extracting power from a powering burst signal being configured to provide electrical power to the electronic device for powering the electronic device may be configured as known in the art, e.g. as described in the above cited paper "Powering the Next Billion Devices with Wi-Fi" of Vamsi Talla et al. Other configurations that may be used are described in Jean-Pierre Joosting: "HARVESTING ENERGY FROM ELECTROMAGNETIC WAVES", April 15, 2015 (currently available at http://www.analog-eetimes.com/news/harvesting-energy-electromagnetic-waves), or Tony Armstrong: "AN INFLEXION POINT FOR ENERGY HARVESTING AND THE INTERNET OF THINGS", July 14, 2014 (currently available at http://www.analog-eetimes.com/content/inflexion-point-energy-harvesting-and-internet-things), or Dixon, B. (2010): "Radio Frequency Energy Harvesting", currently available at http://rfenergyharvesting.com/, or Raju, M. (2008): "Energy Harvesting", currently available at http://www.ti.com/corp/docs/landing/cc430/graphics/slyy018_20081031.pdf.

The electronic device may further comprise a response unit for constructing and transmitting a response signal in response to reception of a powering burst signal dependent on one or more of the time of reception of the last powering burst signal, the time of reception of a last polling signal for polling an electronic device, the strength of the last polling signal or the last powering burst signal, the amount of energy extracted from the last powering signal, the current state of energy available in the electronic device, the current

status of the electronic device. This may help the wireless transmitter to determine if and which steps to take next and what the status of the electronic device is.

The one or more wireless transmitters may be included in a respective user device, in particular in a luminaire or lamp or power outlet, and said one or more electronic devices may include one or more sensors, switches, movement detectors and/or presence detectors.

Generally, one potential field of application of the present invention is lighting systems. Due to the ubiquity of lighting end points as well as their access to power, the lighting systems may evolve from "merely providing light" to becoming the last meter network in the IoT. This creates enormous business opportunities and adds value to the lighting systems. Specifically, the lighting network may evolve to provide wireless connectivity and wireless power over relatively short distances to very constrained devices in the IoT. These may have an extremely limited capacity to store power. Examples for such devices are e.g. environmental sensors (presence or movement, light, temperature, humidity, CO2, door opening sensors, window opening sensors, …) and light switches or other controllers, e.g. for operating blinds, setting temperature in the thermostats, etc. Such devices will be very cheap to produce, green, and flexibly deployed, but need external sources of power and connectivity to function.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter. In the following drawings

Fig. 1 shows a schematic diagram of a first embodiment of a wireless system including a wireless transmitter and an electronic device according to the present invention,

Fig. 2 shows a diagram of a signal as transmitted by a wireless transmitter according to the present invention, and

Fig. 3 shows a schematic diagram of the layout of an electronic device as disclosed in the above cited paper "Powering the Next Billion Devices with Wi-Fi" of Vamsi Talla et al., which layout may also be used according to the present invention,

Fig. 4 shows an exemplary more detailed schematic diagram of the electronic device shown in Fig. 3 as disclosed in said paper of Vamsi Talla et al., which may generally also be used in an electronic device according to the present invention,

Fig. 5 shows a schematic diagram of a second embodiment of a wireless system including a wireless transmitter and an electronic device according to the present invention, and

Fig. 6 shows a schematic diagram of a third embodiment of a wireless system including a wireless transmitter and an electronic device according to the present invention

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a schematic diagram of a first embodiment of a wireless system 1 including a wireless transmitter 10 and one or more electronic devices 20, 30 according to the present invention. The wireless system may be a WiFi system, wherein the wireless transmitter 10 may be included in or represent an access point or router and the electronic devices 20, 30 may be included in or represent any kind of user device having no or only minimum electrical power supply or power storage capacity and being able to communicate via WiFi with the wireless transmitter 10 by use of a wireless receiver. The electronic devices 20, 30 are herein also called harvesting device; a particular example of such electronic devices 20, 30 are IoT (Internet of Things) devices.

The wireless transmitter 10 comprises a transmission unit 11 for wirelessly transmitting signals to an electronic device comprising a wireless receiver. The transmission unit 11 particularly comprises one or more transmitting antennas, as e.g. used in a conventional wireless receiver of a WiFi system. Further, the wireless transmitter 10 comprises a signal construction unit 12 for constructing signals for transmission, said signals including powering burst signals and message signals, a powering burst signal being configured to provide electrical power to one or more electronic device 20, 30 for powering them. The signal construction unit 12 may e.g. be a signal processor or RF circuit. Hereby, the signal construction unit 12 is configured to construct and said transmission unit 11 is configured to transmit a powering burst signal as required and in advance of transmitting message signals. Thus, a powering burst signal is only transmitted if needed by the respective electronic device to perform a desired task, such as to send a response signal to the wireless transmitter 10.

The electronic device 20 comprises (the electronic device 30 is generally constructed accordingly, which is not shown explicitly in Fig. 1) a wireless receiver 21 for wirelessly receiving signals transmitted by the wireless transmitter 10 (or another wireless transmitter in reach of the electronic device 20), said signals including powering burst signals and message signals. The wireless receiver 21 particularly comprises one or more receiving

antennas, as e.g. used in a conventional wireless receiver of a WiFi system. The electronic device 20 further comprises a power extraction unit 22 for extracting power from a powering burst signal. The power extraction unit 22 may be constructed as electronic circuit, as e.g. described in the above cited paper "Powering the Next Billion Devices with Wi-Fi" of Vamsi Talla et al. The electronic device 20 further comprises a task execution unit 23 for performing a desired task using the extracted power. The task execution unit 23 may e.g. be a sensor for sensing a desired parameter, or an actuator for performing an actuation, or a processor for carrying out a desired processing task.

Fig. 2 shows a diagram of a signal 100 as transmitted by a wireless transmitter according to the present invention. The signal 100 comprises one or more message signals 101 containing payload data (i.e. message information) to be transmitted to an electronic device and one or more powering burst signals 102 sent in advance of a message signal 101 in order to enable the electronic device receiving said powering burst signal 102 to extract power from it. The powering burst signal 102 is preferably optimized for highest possible power transfer and does generally not contain payload data (which is, however, not excluded).

Fig. 3 shows a schematic diagram of the layout of an electronic device 40 as disclosed in the above cited paper "Powering the Next Billion Devices with Wi-Fi" of Vamsi Talla et al., which layout may also be used according to the present invention. In this exemplary embodiment three WiFi channels shall be used for power harvesting by the electronic device.

A receiving antenna 21 representing the receiving unit is followed by a rectifier 221 that converts the 2.4 GHz signal into DC power. This power is fed into a DC–DC converter 222 that increases the voltage of the DC signal to match the voltage requirements of the task execution unit 23, e.g. a sensor and/or micro-controller. The rectifier hardware 221 is extremely non-linear with input power, operational frequency and the parameters of the DC–DC converter 222, making it challenging to achieve good harvester sensitivity and efficiency across the 72 MHz band that spans e.g. three WiFi channels. Hence, a matching network 223 is arranged between the receiving antenna 21 and the rectifier 221 to transform the rectifier's impedance to match that of the receiving antenna 21. Since the rectifier's impedance varies significantly with frequency and is dependent on the DC–DC converter 222, all components of the power extraction unit 22 (sometimes also called RF harvester) are co-designed to achieve good impedance matching across the 72 MHz WiFi band. The input of the DC–DC converter 222 affects the input impedance of the rectifier 221.

Thus, if the rectifier 221 can be co-designed with the DC–DC converter 222, the constraints on the matching network 223 can be relaxed.

Fig. 4 shows an exemplary more detailed schematic diagram of the electronic device 40 shown in Fig. 3, which may generally also be used in an electronic device according to the present invention.

At a high level, the rectifier 221 tracks twice the envelope of the incoming signal and converts it into power. Specifically, it adds the positive and negative cycles of the incoming sinusoidal carrier signal to double the amplitude. To do this, it uses a specific configuration of diodes and capacitors as shown in Fig. 4. However, in practice, diodes and capacitors have losses that limit the output voltage of the rectifier. Diodes having low losses, i.e., loss threshold voltage, low junction capacitance and minimal package parasitics and high–quality factor, low-loss UHF-rated capacitors that minimize losses and maximize the rectifier's efficiency and sensitivity are preferred.

Two different embodiments of the DC–DC converter are shown in Fig. 4: a battery recharging version 222a and a battery-free version 222b. The DC–DC converter generally serves two purposes: i) boost the voltage output of the rectifier 221 to the levels required by the task execution unit 23, and ii) make the input impedance of the rectifier 221 less variable across three WiFi channels. The key challenge is the cold-start problem: in a battery-free design, as shown for DC–DC converter 222b, all the hardware components must boot up from 0 V. Practical DC–DC converters, however, have a non-zero minimum voltage threshold. Hence, a DC–DC conversion unit 224b may be used, which can start from input voltages as low as 300 mV, which the rectifier 221 can provide, and boost the output on a storage capacitor C_S to 2.4V. Once the 2.4 V threshold is reached, the DC–DC converter 222 (acting as charge pump) connects the storage capacitor C_S to the output, powering the task execution unit 23.

The DC–DC converter 222a is optimized while recharging a battery 225. Specifically, the battery 225 can provide a minimum voltage level and hence the hardware components need not boot up from 0 V. Hence, a DC–DC conversion unit 224a may be used that contains a boost converter, a battery charger, voltage monitoring solutions and a buck converter. The rechargeable battery 225 is connected to the battery charging node, Vbat, of the DC–DC conversion unit 224a. The boost is used as DC–DC converter to achieve the voltage required to charge the battery 225. Finally, the maximum power point tracking (MPPT) mode of the DC–DC conversion unit 224a is leveraged to tune the input impedance of the DC–DC converter so as to minimize the variation of the rectifier's impedance across

WiFi channels. Specifically, the buck converter's MPPT reference voltage may be set to 200 mV.

With such rectifier and DC–DC converter designs, the constraints on the impedance-matching network 223 have been relaxed. The resulting circuit can match impedances between the rectifier 221 and a 50 Ω antenna 21 across WiFi channels, using a single-stage LC matching network 223. In LC matching networks, inductors are the primary source of losses. To mitigate this, high-frequency inductors may be used which have minimal parasitics and a quality factor of 100 at 2.45 GHz. The resulting matching network 223 consumes less board area than traditional transmission lines and distributed-element based matching networks and can be modified to meet different system parameters without any loss.

Further details about the design and function of the electronic device 40 shown in Figs. 3 and 4 can be found in the cited paper. The general layout of this electronic device 40 can also be used in the electronic device 20, 30 according to the present invention, in particular the design and function of the power extraction unit 22. According to the present invention the electronic device is further adapted to extract power from a powering burst signal being transmitted as required and in advance of message signals.

Fig. 5 shows a schematic diagram of a second embodiment of a wireless system 2 according to the present invention. In this embodiment the wireless system is integrated into a lighting system, i.e. the wireless transmitter 10 is integrated or coupled with a luminaire 50 and the electronic devices are e.g. represented by an occupancy sensor 60 and a wall switch 70. In a practical system one or more luminaires include a respective access point (i.e. a wireless transmitter), which are thus distributed in space, e.g. in a room or building.

In such an integrated lighting system 2 (i.e. including power transfer capability) the wireless transmitter 10 can be easily integrated with the luminaire 50. A typical luminaire 50 comprises the optical part with light generation means 51 which is operated by the lamp driver 52 which is e.g. powered from mains 53. The wireless transmitter 10 can even be powered from the power supply of the lamp driver 52 via supply line 54 and optionally, in extension, provide control information to the driver via signal line 55. The exemplary occupancy sensor 60 and wall switch 70 get powered over WiFi and need no cable connection or battery. The wireless transmitter 10 can be a built-in part of the luminaire 50. Alternatively, it can be a plug-and-play extension to the luminaire 50, which simplifies the installation and planning, particularly if the luminaires are identical and are only later

extended with the required power extraction functionality. This also simplifies wireless transmitter 10 location changes, e.g. when changing room layout. The powering of the occupancy sensor 60 and wall switch 70 over WiFi is made by means of the above described modification to the transmission using powering burst signal(s) and allowing for energy and RF noise optimized operation. Alternatively, each luminaire can still be equipped with a wireless transmitter, and all of the transmitter functionality or selectively its power over WiFi functionality can be enabled and disabled for selected luminaires, e.g. with the goal to achieve the required power coverage with minimal energy waste.

In an exemplary use scenario wireless transmitter 10 (e.g. under control of a luminaire controller; not shown) polls the related in-range light switch(es) 70 and sensor(s) 60 (i.e. the electronic devices) by sending a powering burst signal containing sufficient energy to supply the battery-less electronic device(s) for a specific task. One task can be polling the sensor 60 or the light switch 70. The wirelessly powered electronic device only has to power-up for reading out the sensor or switch status and sending an informative response message to the wireless transmitter 10 (and, thus, to the optional luminaire controller). The wireless transmitter 10 (and the optional luminaire controller) has the ability of powering and thus polling the wirelessly powered electronic devices in range, which are of relevance to itself. It may ignore any communication not intended for itself.

In an embodiment, the wireless transmitter 10 (and the optional luminaire controller) may be programmed to power and poll the wirelessly powered electronic devices in range, which are of interest to other wireless transmitters (and other optional luminaire controllers), and forward the data accordingly. This may require some communication between the wireless transmitters or may be already fully taken care of by the communication protocol layers of the wireless system, e.g. of a WiFi in accordance with IEEE 802.11 and higher.

In fact where reference is made to WiFi this is at least intended to cover one of the publicly available standards of IEEE802.11, 11a, 11b, 11g, 11n and 11ac, but does not preclude other WiFi systems. In particular these versions of the IEEE802.11 standard (and amendments) allow use of the 2.4 and/or the 5.0 GHz band. However, the claimed invention may also be applied advantageously to other versions of the 802.11 standard such as 11ad which provides both an omni-direction and directional transmission scheme, as well as 11af and 11ah.

Fig. 6 shows a schematic diagram of a third embodiment of a wireless system 3 including a wireless transmitter 10' and an electronic device 20' according to the present

invention, which shall be used for explaining further optional elements and functions of the proposed wireless transmitter and electronic device. These optional elements may be used in other combinations and with other embodiments of the wireless transmitter and the electronic device.

In one embodiment the electronic devices can react on the powering burst signal with information on power filling they reached and eventually ask for another or an extended powering burst signal for more electrical energy to accomplish their different tasks. Thus, the wireless transmitter 10' may comprise a reception unit 13 for receiving a response signal from an electronic device and for analyzing one or more parameters of said response signal, in particular the length, bandwidth, frequency, content and/or strength of the response signal. The signal construction unit 12 may then be configured to construct the powering burst signal and/or said transmission unit 11 may be configured to adapt one or more transmission parameter dependent on the result of said analysis.

Further, in an embodiment a memory 14 may be provided to remember these feedbacks per electronic device and to adjust the powering burst signal accordingly dependent on the addressed electronic device. As electronic devices preferably harvest a broad RF band this allows adjusting also for different environments where multiple sources for harvesting may be tabbed.

Accordingly, the electronic device 20' may further comprise a response unit 24 for constructing and transmitting a response signal in response to reception of a powering burst signal dependent on one or more of the time of reception of the last powering burst signal, the time of reception of a last polling signal for polling an electronic device, the strength of the last polling signal or the last powering burst signal, the amount of energy extracted from the last powering signal, the current state of energy available in the electronic device, the current status of the electronic device.

In a further embodiment the electronic devices can react on the powering burst signal with information on their power scavenging and storage capabilities such as the maximum amount of power that can be stored, preferred WiFi frequency, optimal receive direction, power scavenging method etc. The wireless transmitter 10' may also remember these feedbacks per electronic device in the memory 13 and adjust their future powering burst signals. Alternatively, the more permanent elements of the power scavenging and storage capabilities of the electronic devices can be exchanged in a first power information setup protocol.

In a yet further embodiment, the wirelessly powered electronic device 20' may have further rules determining the response conditions, e.g. based on time since the last poll, signal strength of the poll, amount of energy harvested (which may be indicative of the time from the last poll or the signal strength), or its status (e.g. sensor/switch status in case of a sensor/switch as shown in Fig. 5), e.g. only if status changed or increased/decreased by more than a predetermined percentage. Alternatively, the electronic device 20' may be required to always respond with device data (e.g. sensor/switch data). In yet another alternative embodiment, the electronic device 20' may be required to always respond, but the presence/absence of the device status data (e.g. sensor/switch status data) may be dependent on the response conditions; if those are not fulfilled, another message (e.g. a shorter ACK-type message) can be returned instead. Those rules and conditions may be configurable, also over the air.

In a yet further embodiment, the type of response required may be derivable from the powering burst signal, e.g. signal strength and/or the length of the powering burst signal (and optionally from the amount of energy harvested by the electronic device). Short/weak powering burst signals may only provide the electronic device 20' with enough energy to send a short response message (e.g. a sort of heartbeat signal or power status signal), whereas long/strong powering burst signals may provide the electronic device 20' with enough energy to provide a full response. In a particular realization, the powering burst signal itself may be sufficient to poll the electronic device, and the communication packet (i.e. the message signal) may be omitted completely.

The kind of response of the electronic device 20' may be further indicative of the propagation conditions between the wireless transmitter 10' and the electronic device 20' and may be a trigger for changes to the wireless system 3. Such changes may include changing the default antenna orientation, changing the default power level/duration of the powering burst signal, changing the location of the wireless transmitter 10', changing the wireless transmitter responsible for powering a particular electronic device, etc. For optimizing the overall system performance, also reducing the complete transmission length/strength may be of interest to limit interference.

The powering burst signals transmitted by the wireless transmitter 10' may, by its nature, only be receivable in a certain range. To reduce the required packet length to be transmitted by the electronic device 20' (and therefore the amount of energy required for it), and thus to possibly reduce the duration/strength of the powering burst signal (and therefor the interference caused for the entire system), some fields can be omitted from the

communication protocol (e.g. the destination addressing fields at the MAC 802.11 layers). It may require the wireless transmitter 10' to filter the incoming communication, e.g. by the address of interesting electronic device address.

Another embodiment, which may be useful in the lighting system, is as follows: In a given space or for interconnected systems powering burst signals may be synchronized to overlap in order to allow low noise data communication in the pauses between. This will allow optimizing RF transmission power of the remote wireless transmitters.

If the wireless transmitters are in range of each other and/or the electronic device is in range of multiple wireless transmitters, additional (e.g. random, CSMA/CA) delay between the powering burst signal and the actual communication packet (i.e. the message signal) may be introduced. Alternatively, this embodiment can be used in combination with the embodiment explained above, in which the powering burst signal characteristics determine the type of response and the communication packet following the powering burst signal is omitted; the responding electronic devices can solve the channel access themselves.

In a further embodiment lighting installers may have means to use e.g. CAD tools mapping all the installed electronic devices and automatically design placement of wireless transmitters (preferably integrated with/pluggable into fixtures). Also powering burst signal parameters like length, frequency, etc. of the powering burst signal may be automatically adjusted dependent on distance and walls to be trespassed, etc..

In yet another embodiment the design software for installers may allow keeping the bands of transmission separated for neighboring cells. Also if for powering this might not be necessary if the powering burst signals are sent synchronously the channel for message transfer may be set automatically.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain

measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A wireless transmitter for use in a wireless system, said wireless transmitter comprising:

- a transmission unit (11) for wirelessly transmitting signals to an electronic device comprising a wireless receiver, and
- a signal construction unit (12) for constructing signals for transmission, said signals including powering burst signals and message signals, a powering burst signal being configured to provide electrical power to the electronic device for powering the electronic device,

wherein said signal construction unit (12) is further configured to construct a powering burst signal as required to enable the electronic device to receive a message signal and perform a task and said transmission unit (11) is configured to transmit, in advance of transmitting the message signal, the constructed powering burst signal.

2. The wireless transmitter as claimed in claim 1, wherein said transmission unit (11) is configured to transmit said powering burst signal with maximum transmission power.

3. The wireless transmitter as claimed in claim 1, wherein said signal construction unit (12) is configured to optimize said powering burst signal, in particular the signal sequence, the duration and/or information content of said powering burst signal, to enable a wireless receiver (21) to extract as much electrical power as possible from said powering burst.

4. The wireless transmitter as claimed in claim 1, wherein said signal construction unit (12) is configured to construct and said transmission unit (11) is configured to transmit a powering burst signal upon request from a user or from the electronic device (20, 20', 60, 70).

5. The wireless transmitter as claimed in claim 1, wherein said signal construction unit (12) is configured to construct said powering burst signal according to a

power request signal received from an electronic device indicating the power requirement of an electronic device to perform a desired task.

6. The wireless transmitter as claimed in claim 1, wherein said signal construction unit (12) is configured to construct and said transmission unit (11) is configured to transmit a polling signal for polling an electronic device.

7. The wireless transmitter as claimed in claim 1, further comprising a memory (14) for storing one or more transmission parameters of different electronic devices, said one or more transmission parameters including one or more of the power requirements to perform a desired task, the power storage capacity, the power harvesting method, the preferred transmission frequency, the preferred receive direction, wherein said signal construction unit (12) is configured to construct the powering burst signal to be transmitted to a particular electronic device according to the stored one or more transmission parameters of said electronic device.

8. The wireless transmitter as claimed in claim 1,
further comprising a reception unit (13) for receiving a response signal from an electronic device and for analyzing one or more parameters of said response signal, in particular the length, bandwidth, frequency, content and/or strength of the response signal,
wherein said signal construction unit (12) is configured to construct the powering burst signal and/or said transmission unit (11) is configured to adapt one or more transmission parameters dependent on the result of said analysis.

9. The wireless transmitter as claimed in claim 1, wherein said transmission unit (11) is configured to synchronize transmission of said powering burst signal with the transmission of a powering burst signal by one or more further transmission units of the wireless system.

10. An electronic device for use in a wireless system, said electronic device comprising:

- a wireless receiver (21) for wirelessly receiving signals transmitted by a wireless transmitter, said signals including powering burst signals and message signals,
- a power extraction unit (22) for extracting power from a powering burst signal

being configured to provide electrical power to the electronic device for powering the electronic device, a powering burst signal being constructed as required to enable the electronic device to receive a message signal and perform a task and the constructed powering burst signal being transmitted, in advance of the message signal, and

- a task execution unit (23) for performing the desired task using the extracted power.

11. The electronic device as claimed in claim 10, further comprising a response unit (24) for constructing and transmitting a response signal in response to reception of a powering burst signal dependent on one or more of the time of reception of the last powering burst signal, the time of reception of a last polling signal for polling an electronic device, the strength of the last polling signal or the last powering burst signal, the amount of energy extracted from the last powering signal, the current state of energy available in the electronic device, the current status of the electronic device.

12. A wireless transmission method comprising:

- wirelessly transmitting signals to an electronic device comprising a wireless receiver, and

- constructing signals for transmission, said signals including powering burst signals and message signals, a powering burst signal being configured to provide electrical power to the electronic device for powering the electronic device,

wherein a powering burst signal is constructed as required to enable the electronic device to receive a message signal and perform a task and the constructed powering burst signal is transmitted, in advance of transmitting the message signal.

13. A wireless reception method comprising:

- wirelessly receiving signals transmitted by a wireless transmitter, said signals including powering burst signals and message signals,

- extracting power from a powering burst signal being configured to provide electrical power to the electronic device performing said wireless reception method for powering the electronic device, a powering burst signal being constructed as required to enable the electronic device to receive a message signal and perform a task and the constructed powering burst signal being transmitted, in advance of the message signal, and

- performing the desired task using the extracted power.

14. A wireless system comprising

- one or more wireless transmitters (10, 10') as claimed in claim 1 and
- one or more electronic devices (20, 20', 60, 70) as claimed in claim 10.

15. The wireless system as claimed in claim 14, wherein said one or more wireless transmitters are included in a respective user device, in particular in a luminaire or lamp, and said one or more electronic devices include one or more sensors, switches, movement detectors and/or presence detectors.

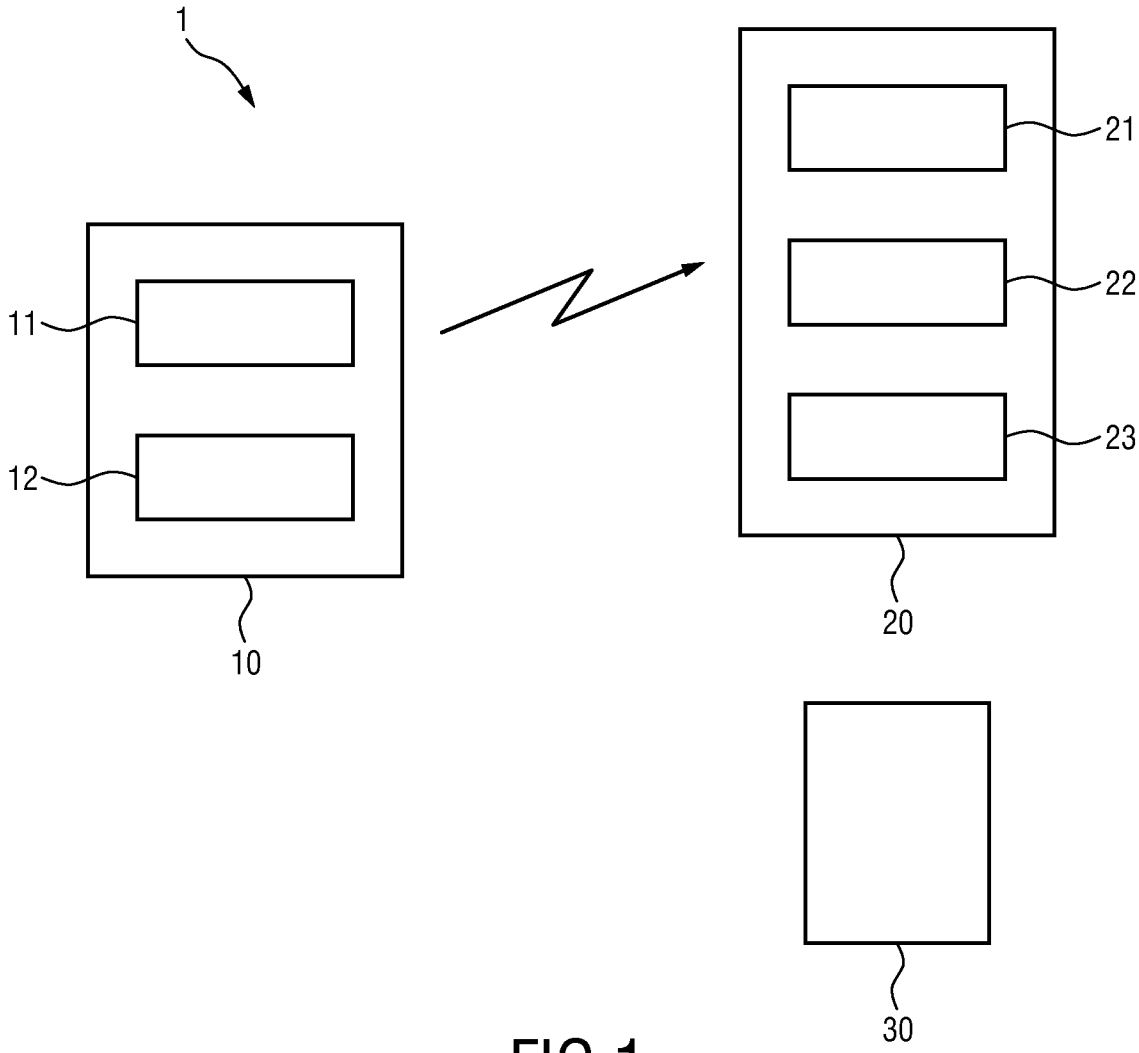


FIG.1

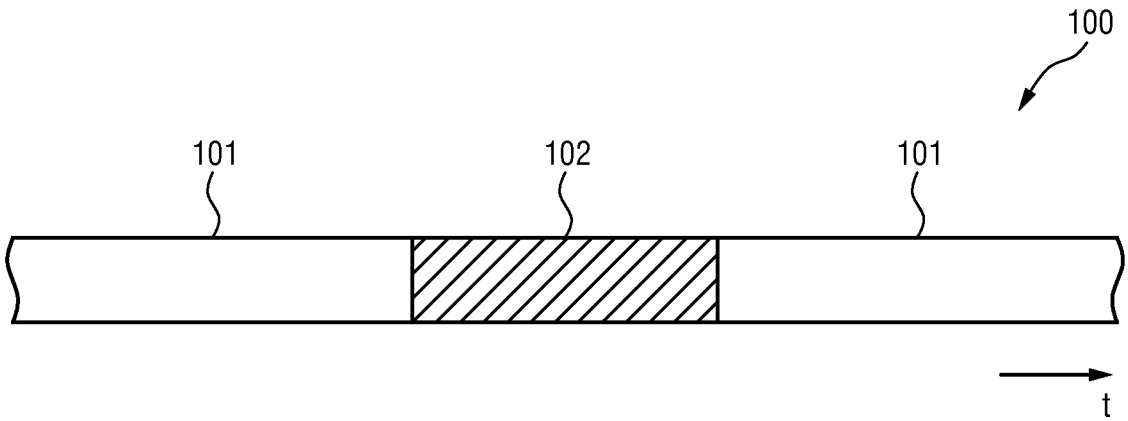


FIG.2

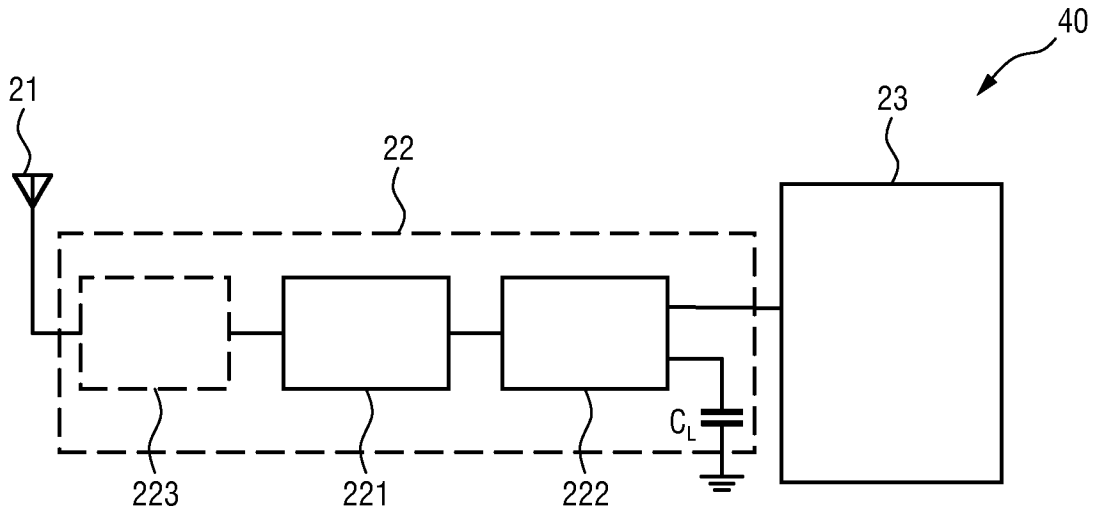

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C_L
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222

FIG.3

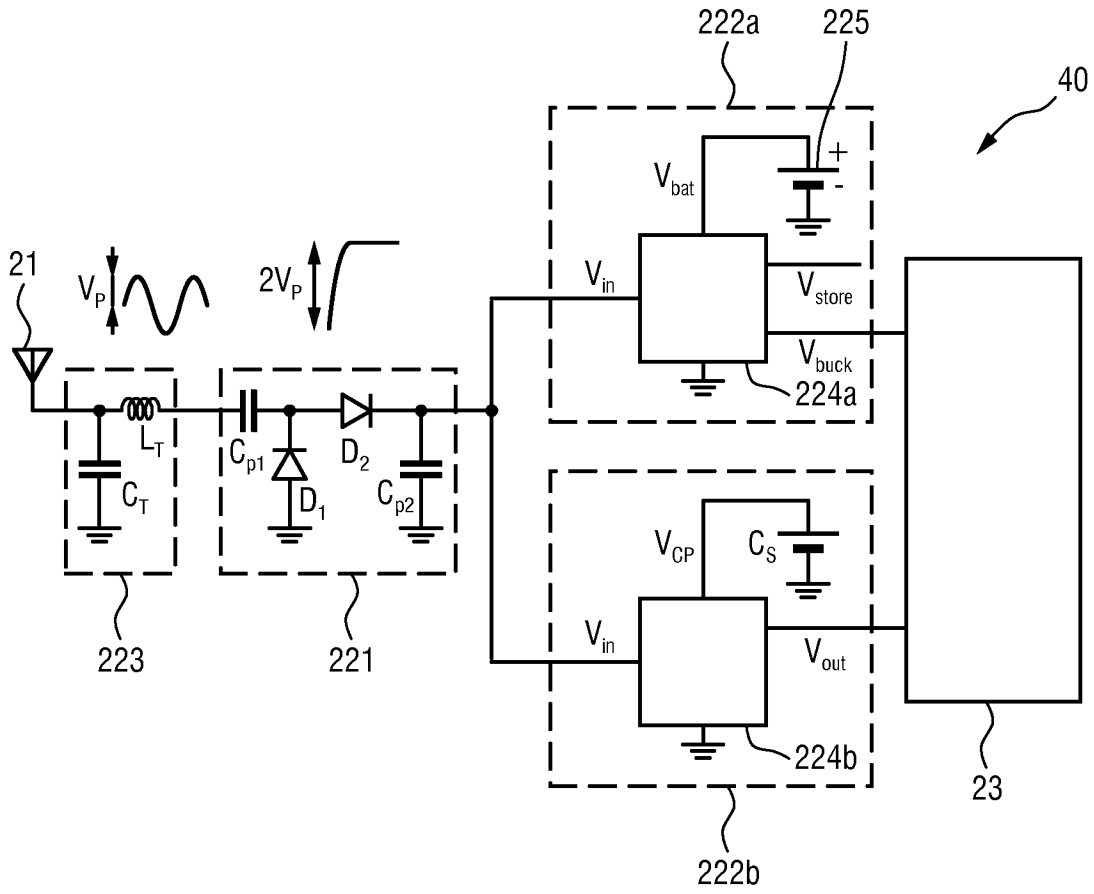

222a
225
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+
-
21
V_P
$2V_P$
V_{in}
V_{store}
V_{buck}
224a
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C_T
C_{p1}
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23
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FIG.4

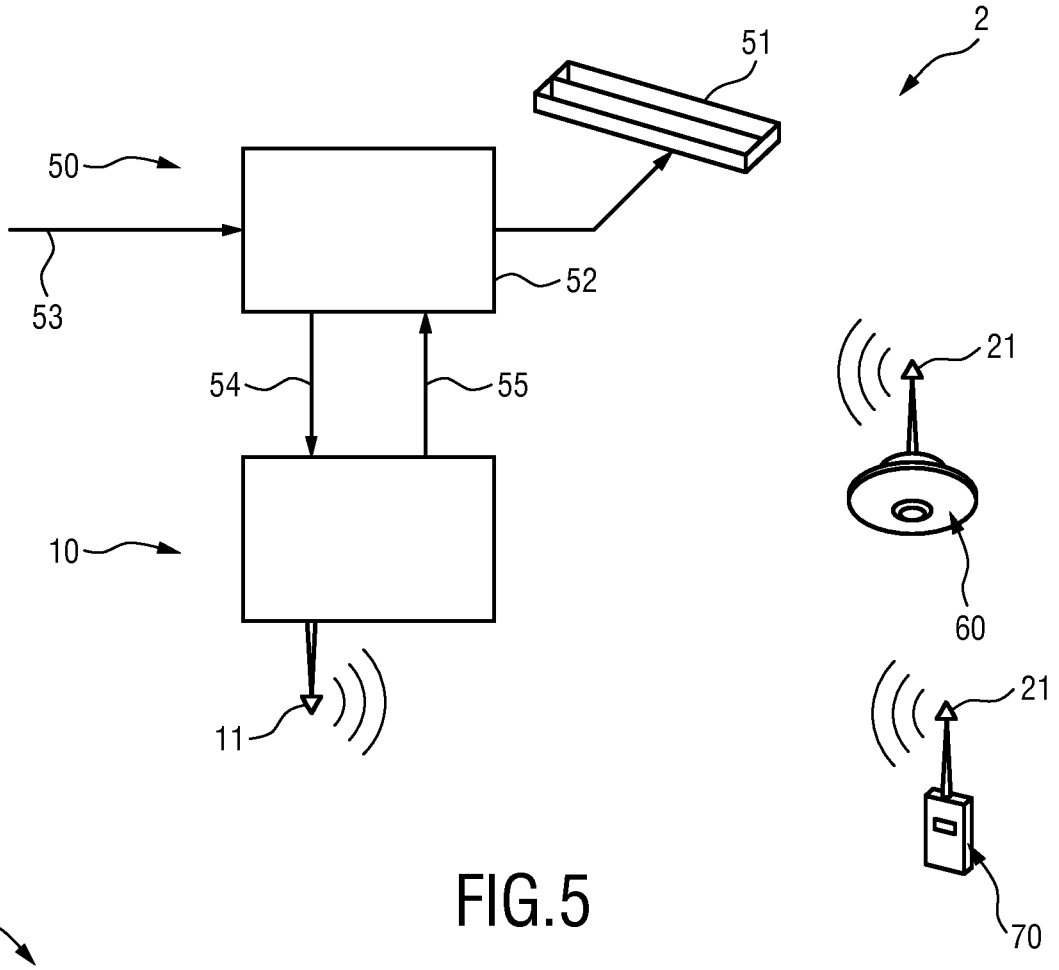


FIG.5

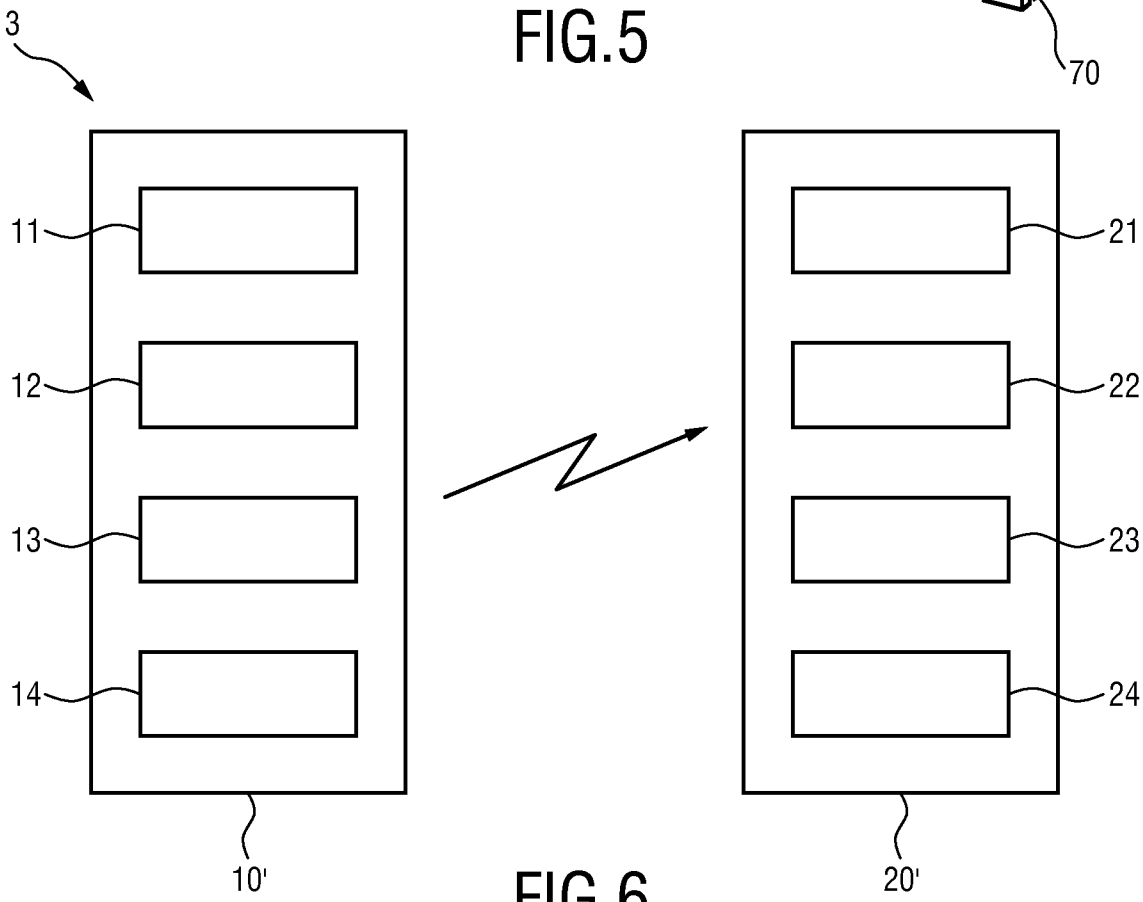


FIG.6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/059458

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B5/00 H04L29/08 H04W84/18 H05B37/02 G06K19/07
ADD.

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)
H04B H04L H04W H05B G06K

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/303741 A1 (MALIK RAHUL [US] ET AL) 22 October 2015 (2015-10-22) paragraphs [0030] - [0087]; claims 21-23; figures 3,4,8,9E,10	1-15
X	WO 2006/058309 A2 (PATRIOT SCIENT CORP [US]; NUNALLY PATRICK [US]) 1 June 2006 (2006-06-01) paragraphs [0041], [0043] - [0056]; figures 1B,2	1-5, 7-10, 12-14
X	US 2013/121176 A1 (ADDEPALLI SATEESH K [US] ET AL) 16 May 2013 (2013-05-16) paragraphs [0016], [0018], [0019], [0031], [0032], [0046]; figures 1,2,10	1,9,10, 12-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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	Date of mailing of the international search report
14 July 2017	24/07/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Fouasnon, Olivier

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/059458

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		WO 2006058309 A2	01-06-2006
US 2013121176 A1	16-05-2013	EP 2781074 A1	24-09-2014
		US 2013121176 A1	16-05-2013
		WO 2013074863 A1	23-05-2013