

HARMONIC-BASED COMMUNICATION AND POWER TRANSFER SYSTEM AND METHOD

FIELD OF INVENTION

- 5 The present invention relates broadly to a harmonic-based communication and power transfer system and its components and corresponding methods.

BACKGROUND

- 10 Any mention and/or discussion of prior art throughout the specification should not be considered, in any way, as an admission that this prior art is well known or forms part of common general knowledge in the field.

Wireless power transfer to devices is expected to play a crucial part for extending of a device's lifetime for prolonged operation, enabling set-and-forget approach, for example for Internet-of-things (IOT) devices such as sensors.

- 15 The potential benefits of wireless power transfer to devices also include cost saving on battery replacement/maintenance, which will be substantial in the near future where thousands of e.g. IOT devices will be used. This also reduces the environmental impact caused by toxic chemicals released from batteries upon disposal.

- 20 Existing systems and method for wireless power transfer to devices generally focus on passive beam forming techniques, hence lacking intelligent control feature(s). Also, while some existing systems provide for communication in addition to power transfer, including for active beam forming techniques, they typically either use only signal strength of harmonics of the power transmission signal for data transmission, which limits the communication range and is strongly affected by noise, or non-harmonic methods requiring complex hardware and
25 algorithms.

Embodiments of the present invention provide a harmonic-based communication and intelligent power transfer system that seeks to address at least one of the above problems.

SUMMARY

- 30 In accordance with a first aspect of the present invention there is provided a system for wireless power transfer comprising:

one or more power receivers configured to be coupled to respective devices for power management of the respective devices; and

one or more adaptive power transmitters configured to transmit radio-frequency energy having a frequency f_0 or at least a pair of frequencies f_1, f_2 via beam forming to the one or more power receivers and configured to receive status data from the one or more power receivers;

5 the one or more power receivers being configured to transmit the status data to at least one of the one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$; and

10 wherein the one or more adaptive power transmitters are configured to steer a formed beam of the radio frequency energy toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic or the intermodulation product.

In accordance with a second aspect of the present invention there is provided an adaptive power transmitter comprising:

15 a transmitter element configured to transmit radio-frequency energy having a frequency f_0 or at least a pair of frequencies f_1, f_2 via beam forming to one or more power receivers;

a receiver element configured to receive status data from the one or more power receivers via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$; and

20 a steering element to steer a formed beam of the radio frequency energy toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic or the intermodulation product.

In accordance with a third aspect of the present invention there is provided a power receiver comprising:

25 a receiver element for receiving radio-frequency energy having a frequency f_0 or at least a pair of frequencies f_1, f_2 via beam forming;

an interface configured to be coupled to a device for power management of the device; and

30 a transmitter element configured to transmit status data to one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$.

In accordance with a fourth aspect of the present invention there is provided a method for wireless power transfer comprising the steps of:

35 transmitting, using one or more adaptive power transmitters, radio-frequency energy having a frequency f_0 or at least a pair of frequencies f_1, f_2 via beam forming to one or more power receivers;

transmitting, using the one or more power receivers, status data to at least one of the one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$;

receiving, using the one or more adaptive power transmitters, the status data from the one or more power receivers; and

steering, using the one or more adaptive power transmitters, a formed beam of the radio frequency energy toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic or the intermodulation product.

In accordance with a fifth aspect of the present invention there is provided a method for wireless power transmission comprising the steps of:

transmitting, using an adaptive power transmitter, radio-frequency energy having a frequency f_0 or at least a pair of frequencies f_1, f_2 via beam forming to one or more power receivers;

receiving, using the adaptive power transmitter, status data from the one or more power receivers via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$; and

steering, using the adaptive power transmitter, a formed beam of the radio frequency energy toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic or the intermodulation product.

In accordance with a sixth aspect of the present invention there is provided a method for wireless power reception comprising the steps of:

receiving, using a power receiver, radio-frequency energy having a frequency f_0 or at least a pair of frequencies f_1, f_2 via beam forming from one or more adaptive power transmitters; and

transmitting status data to the one or more adaptive power transmitters via carrier frequency modulation via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 shows a schematic diagram illustrating a wireless power transfer system according to an example embodiment.

Figure 2 shows a flow chart illustrating a wireless power transfer algorithm according to an example embodiment.

- 5 Figure 3 shows a schematic diagram illustrating a receiver/device according to an example embodiment.

Figure 4 shows a schematic diagram of an adaptive power transmitter 400 according to an example embodiment

- 10 Figure 5 shows a schematic diagram of power receiver 500 according to an example embodiment

Figure 6 shows a flow chart illustrating a method for wireless power transfer according to an example embodiment.

Figure 7 shows a flow chart illustrating a method for wireless power transfer according to an example embodiment.

- 15 Figure 8 shows a flow chart illustrating a method for wireless power reception according to an example embodiment.

Figure 9 shows a schematic diagram illustrating a transmitter according to an example embodiment.

20 DETAILED DESCRIPTION

A wireless power transfer system according to an example embodiment can comprise the following:

1. Adaptive Power Transmitter

- Enable remote power delivery by radiating radio-frequency energy toward the targeted
25 electronic devices or sensors to provide power.
- Enable data communication between the receivers and the transmitters based on the harmonics generated from the receiver.
- Use of data collected from the receiver (e.g. battery status level, device ID, location,
30 ...) to automatically adjust the transmitted power level. This features advantageously enables an adaptive power charging feature, for instance in the event of a certain device being of critical low power level - upon receiving this information, the power transmitter can steer the power beam towards the devices momentarily to bring up the power level.

2. Multi-functional Power Receiver

- Able to receive Radio-frequency power and convert to DC to power the electronic devices or sensors.
- Able to use the harmonic components originated from the rectifier as the carrier frequency for communication between receivers and transmitters.

5 The transmitter and receiver individually also constitute complementary embodiments of the present invention.

Embodiment of the present invention can have one or more of the following advantages compared to existing systems:

- 10 • Automatic adjustment of power level and radiation pattern of the power transmitter based on the conditions of the targeted electronic devices or sensors. Existing systems typically focus on passive beam forming technique without such adjustment/control feature.
- Harmonic-based communication with conventional modulation technique to ensure security and enhance communication range. Existing systems typically use only signal strength of the harmonics without modulation, which limits the communication range and strongly affected by noise.
- 15 • Example embodiments of the present invention can advantageously enable simultaneous data and power transfer for enhanced functionality.

20 Figure 1 shows a schematic diagram illustrating a system 100 according to an example embodiment, comprising one or more power transmitters 102, 104 and a plurality of power receivers 106-108.

The power transmitters 102, 104 are configured to:

- Radiate radio-frequency power 110, 112 toward the power receivers 106-108 to provide remote power using a frequency f_0 or at least a pair of frequencies f_1 & f_2 .
- 25 • Function as a gateway to collect data from the devices coupled to, or integrated with, the receivers 106-108, here in the form of sensors 114-116. The data may represent information such as, but not limited to, battery status, device ID, location, etc. The data communication, indicated by arrows 118-120 is harmonic-based, where the carrier frequency is one of the harmonic nf_0 , $n=2, 3, \dots$ or one of the intermodulation products $lf_1 \pm mf_2$, $l=1, 2, \dots$ and $m = 1, 2, \dots$ generated by the power receivers 106-108.
- 30 • Automatically adjust the power level and the radiation pattern of transmitting antenna e.g. 107, 109 for the radiated radio-frequency beams 110, 112 based on the data collected from the sensors 114-116, i.e. based on the conditions and information gathered from sensors 114-116.
- 35 • Perform communication/relay of information 121 between multiple transmitters 102, 104 to enhance the system's 100 efficiency and coverage range.

The power receivers 106-108 are configured to:

- Capture radio-frequency energy from the transmitters 102, 104 and convert to DC to power the electronic parts of the sensors 114-116.
- Extract the harmonic or intermodulation components passively generated from the rectifier (part of the power receivers 106-108 circuits, described in more detail below) to use as carrier frequency for communication.
- Modulate the carrier frequency according to data from the sensors 114-116 representing the information of the sensors 114-116 to be transmitted back (compare arrows 118-120) to the power transmitters 102, 104 for further processing. Suitable carrier frequency modulation techniques are understood in the art and will not be described in detail here. Reference is made, by way of example only, to Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), or Frequency Shift Keying (FSK).

The system 100 according to an example embodiment is configured to apply an algorithm to adaptively control the power level and radiation pattern of the power transmitters 102, 104, for example when receiving low battery status. Figure 2 shows a flowchart 200 illustrating the algorithm according to an example embodiment, as described below:

Upon start/initiation of the system, the power transmitter is in a default state 202, in which the transmitter is configured to radiate a wide coverage beam, with a medium power level.

At step 204, collection of information from the receivers/sensors covered by the wide coverage beam is performed.

- At step 206, based on the battery status level of the covered receivers/sensors, it is determined whether any one or more of the receivers/sensors has a low battery status.

If a receiver/sensor has a low battery status, the closest transmitter is selected at step 208, based on the proximity of power transmitters to the receiver/sensor with the low battery status. The proximity data can be stored within the on-board memory of the transmitter, or on the cloud and can be accessed when necessary, according to example embodiments.

At step 210, a beam-steering high-power mode is activated on the selected power transmitter.

At step 212, the radiation pattern of the antenna is calculated based on the location of the receiver/sensor with the low battery status. Both direction and angular width/spread of the radiation pattern is adjusted in an example embodiment, noting that direction and/or angular width/spread can be adjusted in various embodiments.

At step 214, the energy beam is automatically steered toward the receiver/sensor with the low battery status, based on the direction of the calculated radiation pattern. The mechanism of beam steering is understood in the art and will not be described in detail here. Reference is made, by way of example only, to use of phase array antenna, retrodirective array, time-modulated antenna array, or Butler matrix.

Power is transmitted toward the calculated direction/angular width/spread, until the battery level of the receiver/sensor with the low battery status has increased to a stable/desired level. It is noted that the actual transmit power can be increased to a higher level, and/or the increase

in power can be achieved by the reduced coverage area of the steered beam, as long as a relevant maximum allowable power is not exceeded. For example, the maximum allowable power may be following Media Development Authority (IMDA)/ Federal Communications Commission (FCC) guidelines for power transmitting device, which varies with different operating frequencies and countries.

If more than one receiver/sensor is determined at step 206 as having low battery status, steps 208 to 214 can be performed sequentially, e.g. starting with the receiver/sensor having the lowest battery level, or in parallel, e.g. when multiple transmitters are available.

Returning to Figure 1, transmitter 102 has been shown in the beam steering high-power mode for charging the receiver 108/sensor 114 using steered beam 110, whereas transmitter 104 has been shown in the default state with medium power level and wide coverage beam 112.

In an example embodiment, one or more of the power transmitter(s) also has a power saving mode, which is activated when, for example, the battery status of all covered receivers/sensors are at a stable/desired level. A timer circuit is then activated to bring down the power consumption of the transmitter(s), by reducing the power of the coverage beam, or by putting the system into sleep by temporarily halting the power transmission. The transmitter can exit the power saving mode, for example when it receives requests from receivers/sensors, and/or when a low battery status is determined for one or more of the receivers/sensors, and/or when the pre-determined standby duration is complete.

Figure 3 shows a schematic diagram illustrating the power receiver e.g. 108 according to an example embodiment. It comprises:

- Receiving antenna 300 to capture the radio-frequency energy generated from the transmitter.
- A rectifier circuit 302 (e.g. diode-based or CMOS-based) coupled to the antenna 300 to convert the radio-frequency energy received by the antenna 300 to DC.
- A communication module circuit 304 coupled to the rectifier to extract the harmonics $n f_0$, $n=2, 3$ or the intermodulation products $n f_1 \pm m f_2$, $n=1, 2, \dots$ and $m = 1, 2, \dots$, which are generated inherently at an output of the rectifier circuit 302.
- A power management module 306 to store and regulate the converted DC power to ensure compatibility with attached electronic devices, e.g. sensor 114. It is noted that “store” here means the power management module 306 in this example embodiment includes a storage element – e.g. rechargeable battery, supercapacitor, capacitor, etc.; there are several ways the sensor e.g. 114 can draw power according to various embodiments – (1) from its own rechargeable battery and the power management module helps to recharge the battery, (2) from both its own rechargeable battery and the power management module’s 306 storage element, depending on which source has sufficient power, and (3) from the power management module’s 306 storage element only.

- The sensor e.g. 114 (provided with its own microcontrollers, not shown) are coupled to the power management module 306 for power supply and use one (or more) of the harmonics nf_0 or the intermodulation products $nf_1 \pm mf_2$ as the carrier frequency to send data 308 back to the power transmitter via the communication module circuit 304. It is noted that the sensor e.g. 114 may also draw power supply from its own battery, as described above.

The one or more harmonics nf_0 or the one or more intermodulation products $lf_1 \pm mf_2$ to be used by each receiver are preferably (uniquely) assigned to the respective receivers in advance. In different embodiments, more than two frequencies f_1 & f_2 can be used, and corresponding intermodulation products.

- 10 It is noted that in an example embodiment low order harmonics without amplification. The power level is found to be sufficiently strong for data transfer up to a certain range. Use of amplification, which can for example be part of the communication module, is also considered in different embodiments to boost the reading range depending on the available power budget.

- 15 It is noted that the physical boundary between what is the receiver (compare e.g. numeral 108 in Figure 3) and what is the device/sensor (compare e.g. numeral 114 in Figure 3) can be quite variable according to example embodiments – in other words other than being provided as respective physical units, they may be fully or partially integrated. In a currently preferred embodiment, the receiver and the device/sensor are fully integrated.

- 20 It is noted that while two antenna elements 300a, 300b are shown in Figure 3, coupled to the rectifier circuit 302 and the communication module 304, respectively, a single antenna element may be coupled to both the rectifier circuit and the communication module in different example embodiments.

Figure 9 shows a schematic diagram illustrating the transmitter e.g. 102 according to an example embodiment. It comprises:

- 25 • A frequency generator 900 for generating the frequency f_0 or the pair of frequencies f_1 & f_2 and coupled to a beamforming network 902.
- Transmitting antenna array 904 coupled to the beamforming network 902 to transmit the radio-frequency energy in a formed beam using the frequency f_0 or the pair of frequencies f_1 & f_2 .
- 30 • Receiving antenna 906, communication block 908, and a micro controller unit, MCU, 910 to receive and capture the status data from the power receiver(s) on the carrier frequency, i.e. one of the harmonics nf_0 , $n=2, 3$ or the intermodulation products $lf_1 \pm mf_2$, $l=1,2,\dots$ and $m=1,2,\dots$. The MCU 910 is coupled to the frequency generator 900 and the beamforming network 902, for implementing power delivery to the target power receiver(s).

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In one embodiment, a system for wireless power transfer comprises one or more power receivers configured to be coupled to respective devices for power management of the

respective devices; and one or more adaptive power transmitters configured to transmit radio-frequency energy having a frequency f_0 or at least a pair of frequency f_1, f_2 via beam forming to the one or more power receivers and configured to receive status data from the one or more power receivers; the one or more power receivers being configured to transmit the status data to at least one of the one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$; and wherein the one or more adaptive power transmitters are configured to steer a formed beam of the radio frequency energy toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic nf_0 or the intermodulation product.

The one or more adaptive power transmitters may be configured to transmit and receive data communication to and from another one of the one or more adaptive power transmitters.

The one or more adaptive power transmitters may be configured to execute an algorithm to adjust a power level and radiation pattern of the transmitted radio-frequency energy based on the received status data. The algorithm may comprise the one or more adaptive power transmitters being configured to operate in a default state and to change to operating in a mode with higher power compared to the default state based on the received status data. The algorithm may comprise the one or more adaptive power transmitters being configured to operate in a power saving mode with lower power compared to the default state based on the received status data.

The one or more power receivers may comprise respective rectifiers for conversion of the radio-frequency to DC and for extracting the harmonic nf_0 or the intermodulation product.

The one or more power receivers may be coupled to the respective devices for receiving information about the device for generating the status data for transmission via the carrier frequency modulation using the harmonic nf_0 or the intermodulation product.

Figure 4 shows a schematic diagram of an adaptive power transmitter 400 according to an example embodiment comprising a transmitter element 402 configured to transmit radio-frequency energy having a frequency f_0 or at least a pair of frequency f_1, f_2 via beam forming to one or more power receivers; a receiver element 404 configured to receive status data from the one or more power receivers via carrier frequency modulation using a harmonic nf_0 , $n=2, 3...$ or an intermodulation product $lf_1 \pm mf_2$, $l=1,2,...$ and $m = 1,2,...$; and a steering element 406 configured to steer a formed beam of the radio frequency energy toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic nf_0 or the intermodulation product.

The adaptive power transmitter 400 may be configured to transmit and receive data communication to and from another adaptive power transmitter.

The adaptive power transmitter 400 may be configured to execute an algorithm to adjust a power level and radiation pattern of the transmitted radio-frequency energy based on the received status data. The algorithm may comprise the adaptive power transmitter 400 being configured to operate in a default state and to change to operating in a mode with higher power compared to the default state based on the received status data. The algorithm may comprise the adaptive power transmitter 400 being configured to operate in a power saving mode with lower power compared to the default state based on the received status data.

Figure 5 shows a schematic diagram of power receiver 500 according to an example embodiment comprising a receiver element 502 for receiving radio-frequency energy having a frequency f_0 or at least a pair of frequency f_1, f_2 via beam forming from one or more adaptive power transmitters; an interface 504 configured to be coupled to a device (not shown) for power management of the device; and a transmitter element 506 configured to transmit status data to the one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3, \dots$ or an intermodulation product $lf_1 \pm mf_2$, $l=1, 2, \dots$ and $m = 1, 2, \dots$

The power receiver 500 may comprise a rectifier 508 for conversion of the radio-frequency to DC and for extracting the harmonic or the intermodulation product.

The interface 504 may be configured for receiving information about the device for generating the status data for transmission via the carrier frequency modulation using the harmonic nf_0 or the intermodulation product.

Figure 6 shows a flow chart 600 illustrating a method for wireless power transfer according to an example embodiment. At step 602, radio-frequency energy having a frequency f_0 or at least a pair of frequency f_1, f_2 is transmitted, using one or more adaptive power transmitters, via beam forming to one or more power receivers. At step 604, status data is transmitted, using the one or more power receivers, to at least one of the one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3, \dots$ or an intermodulation product $lf_1 \pm mf_2$, $l=1, 2, \dots$ and $m = 1, 2, \dots$. At step 606, the status data is received, using the one or more adaptive power transmitters, from the one or more power receivers. At step 608, a formed beam of the radio frequency energy is steered, using the one or more adaptive power transmitters, toward a target power receiver out of the one or more power receivers for targeted energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic nf_0 or the intermodulation product.

Figure 7 shows a flow chart 700 illustrating a method for wireless power transfer according to an example embodiment. At step 702, radio-frequency energy having a frequency f_0 or at least a pair of frequency f_1, f_2 via beam forming is transmitted, using an adaptive power transmitter, to one or more power receivers. At step 704, status data is received, using the adaptive power transmitter, from the one or more power receivers via carrier frequency modulation using a harmonic nf_0 , $n=2, 3, \dots$ or an intermodulation product $lf_1 \pm mf_2$, $l=1, 2, \dots$ and $m = 1, 2, \dots$. At step 706, a formed beam of the radio frequency energy is steered, using the adaptive power transmitter, toward a target power receiver out of the one or more power receivers for targeted

energy transfer to the target power receiver based on the status data received from the target power receiver via the carrier frequency modulation using the harmonic nf_0 or the intermodulation product.

Figure 8 shows a flow chart 800 illustrating a method for wireless power reception according to an example embodiment. At step 802, radio-frequency energy having a frequency f_0 or at least a pair of frequency f_1, f_2 is received, using a power receiver, via beam forming from one or more adaptive power transmitters. At step 804, status data is transmitted, using the power receiver, to the one or more adaptive power transmitters via carrier frequency modulation using a harmonic nf_0 , $n=2, 3, \dots$ or an intermodulation product $lf_1 \pm mf_2$, $l=1, 2, \dots$ and $m = 1, 2, \dots$.

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Embodiments of the present invention address, for example, the following problems:

- Extension of a device's, e.g. sensor's, lifetime through wireless power transmission for prolonged operation, enabling set-and-forget approach for e.g. Internet-of-things (IOT) devices such as sensors.
- Cost saving on battery replacement/maintenance, which will be substantial in the near future where thousands of e.g. IOT devices such as sensors will be used.
- Reduce environmental impact caused by toxic chemicals released from battery upon disposal.
- Provide a sustainable powering solution for battery-operated devices such as sensors
- Enable realization of battery-free sensors. It is noted that for such realization, the preferred choice of storage element for the power management module will be capacitor/supercapacitor so that the realization can still be considered as battery-free and with no separate battery for the sensor.
- Combine both power and data transfer in the same hardware.

Embodiments of the present invention can have one or more of the following features and associated benefits/advantages:

Feature	Benefit/Advantage
Harmonic-based communication for Power Receiver	Majority of existing sensors with communication feature (e.g. Bluetooth, LoRa, WiFi) has high power consumption because of the necessity to generate the carrier frequency. Embodiments of the present invention <u>recycle</u> the harmonic or the intermodulation components generated by the rectifier (part of the power receiver) as carrier frequency for data communication; hence it will help to reduce the power consumption and the complexity of the electronic devices or sensors. Appropriate

	modulation techniques can be employed to ensure security and enhance communication range, as is understood in the art.
Adaptive Power Charging for Power Transmitter	Based on the data collected from the devices such as the sensors (e.g. battery status, device ID, location, ...), the power transmitter can determine the power level transmitted and the radiation pattern of its antenna. A number of examples are described below: • In default state, the power transmitter will enable wide-coverage power transmitting mode, • In the event the power levels of all covered sensors are stable/at desired level, the power transmitter may temporarily go to standby mode for power saving, • In the event when a particular device's power level (or battery level) has reach a critically low level, the power transmitter uses beam-steering technique to focus the transmitted power towards the targeted sensors until the sensor's power level has increased to a stable/desired level.

The various functions or processes disclosed herein may be described as data and/or instructions embodied in various computer-readable media, in terms of their behavioral, register transfer, logic component, transistor, layout geometries, and/or other characteristics.

- 5 Computer-readable media in which such formatted data and/or instructions may be embodied include, but are not limited to, non-volatile storage media in various forms (e.g., optical, magnetic or semiconductor storage media) and carrier waves that may be used to transfer such formatted data and/or instructions through wireless, optical, or wired signaling media or any combination thereof. Examples of transfers of such formatted data and/or instructions by carrier waves include, but are not limited to, transfers (uploads, downloads, e-mail, etc.) over the internet and/or other computer networks via one or more data transfer protocols (e.g., HTTP, FTP, SMTP, etc.). When received within a computer system via one or more computer-readable media, such data and/or instruction-based expressions of components and/or processes under the system described may be processed by a processing entity (e.g., one or more processors) within the computer system in conjunction with execution of one or more other computer programs.

- Aspects of the systems and methods described herein, such as the adaptative power transmitter and its components, and the receiver and its components, may be implemented as functionality programmed into any of a variety of circuitry, including programmable logic devices (PLDs), such as field programmable gate arrays (FPGAs), programmable array logic (PAL) devices, electrically programmable logic and memory devices and standard cell-based devices, as well as application specific integrated circuits (ASICs). Some other possibilities for implementing aspects of the system include: microcontrollers with memory (such as electronically erasable programmable read only memory (EEPROM)), embedded microprocessors, firmware,

software, etc. Furthermore, aspects of the system may be embodied in microprocessors having software-based circuit emulation, discrete logic (sequential and combinatorial), custom devices, fuzzy (neural) logic, quantum devices, and hybrids of any of the above device types. Of course the underlying device technologies may be provided in a variety of component types, 5 e.g., metal-oxide semiconductor field-effect transistor (MOSFET) technologies like complementary metal-oxide semiconductor (CMOS), bipolar technologies like emitter-coupled logic (ECL), polymer technologies (e.g., silicon-conjugated polymer and metal-conjugated polymer-metal structures), mixed analog and digital, etc.

10 The above description of illustrated embodiments of the systems and methods is not intended to be exhaustive or to limit the systems and methods to the precise forms disclosed. While specific embodiments of, and examples for, the systems components and methods are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the systems, components and methods, as those skilled in the relevant art will recognize. The teachings of the systems and methods provided herein can be applied to other processing 15 systems and methods, not only for the systems and methods described above.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive. 20 Also, the invention includes any combination of features described for different embodiments, including in the summary section, even if the feature or combination of features is not explicitly specified in the claims or the detailed description of the present embodiments.

In general, in the following claims, the terms used should not be construed to limit the systems and methods to the specific embodiments disclosed in the specification and the claims, but 25 should be construed to include all processing systems that operate under the claims. Accordingly, the systems and methods are not limited by the disclosure, but instead the scope of the systems and methods is to be determined entirely by the claims.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as 30 opposed to an exclusive or exhaustive sense; that is to say, in a sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "hereunder," "above," "below," and words of similar import refer to this application as a whole and not to any particular portions of this application. When the word "or" is used in reference to a list of two or more items, that 35 word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.