

DUAL MODE WIRELESS CHARGING RECEIVER

BACKGROUND

[0001] Attempt to combine wireless charging with near field communication (NFC) in a mobile device's accessory, and subsequently into the mobile device itself, has been gaining some traction lately. For example, Powermat Ltd., recently announced that some of their after-market wireless charging accessories would include NFC antenna to increase adoption of wireless charging and NFC. Presently, wireless charging and NFC are packaged together but completely independent of each other. For example, wireless charging coil with its corresponding circuitry in both wireless transmitter and wireless receiver are completely independent of the NFC antenna and its corresponding circuitry. It is therefore a costly approach in terms of implementation and precludes certain types of transactions and actions between two non-NFC enabled devices. Ideally same circuitry on wireless receiver side should be able to receive power to charge mobile devices and transmit power to another wireless receiver to perform an action or transaction.

[0002] The actions and transactions are, for example, virtual wallet, unlocking a luggage, unlocking a safe, unlocking a computer, turning on security features, travel-pass for commuter train, boarding pass for flights, charging another mobile device etc. Moreover, flexibility of no authentication, one-way authentication, or two-way authentication can be exercised with varying degree of encryption depending upon the end application. Also the actions and transactions are better served when security features are built into the hardware of the mobile device. If security features are not built into the hardware of the mobile device, the user is dependent on a software application on the mobile device to offer security features. The software application implementations may or may not offer security features. For example, a user who loses his/her credit card in a weak software application kind of credit card theft may not know of credit card theft for some time to come. Moreover, conventional wireless receivers lack the ability to transform into a wireless transmitter for charging a secondary wireless charging receiver.

[0003] Hence, there is a need for a dual mode wireless charging receiver with security features built into the hardware of the mobile device that receives wireless power, in one mode, to charge, for example, a mobile device, transmits power, in another mode, to a secondary wireless charging receiver to perform an action or transaction, where such an action or transaction is made inherently secure and reliable via the two-way communication and security capabilities of the dual mode wireless charging receiver and that transforms into a wireless transmitter for charging a secondary wireless charging receiver.

SUMMARY OF THE INVENTION

[0004] A dual mode wireless charging receiver configured to selectively apply a received power to a load device and utilize at least a part of the power to power-up, communicate and charge a secondary wireless power receiver is provided. The dual mode wireless charging receiver comprises a first circuitry and a second circuitry. The first circuitry comprises an impedance network, a switch network, a filter capacitor, and one or more switches. The second circuitry comprises a security engine configured to authenticate, decrypt and encrypt a data transfer between the dual mode wireless charging receiver and the secondary wireless power receiver, a control logic circuit, and a modulator/demodulator circuit. The dual mode wireless charging receiver can operate in a charging mode and a communication mode. In the charging mode, dual mode wireless charging receiver configures the first circuitry to receive the power from a wireless power transmitter. The first circuitry, based on an input from the control logic circuit is configured to change the impedance of the impedance network and topology of the switch network to obtain a modified form of the received power, and apply the modified form of the power to the load device, for example, a battery. In a communication mode, the dual mode wireless charging receiver configures the first circuitry, based on an input from the control logic circuit, to change the topology of the switch network and the impedance of the impedance network to transmit at least part of the modified power to the secondary wireless power receiver to power-up the secondary wireless power receiver. The second circuitry is configured to identify a type of the secondary wireless

power receiver and identify a wireless power protocol of the secondary wireless power receiver. The first circuitry is configured as an inverter or a rectifier depending upon the mode of operation of the dual mode wireless charging receiver. In the charging mode, the first circuitry is configured as rectifier to convert alternating current to direct current (ac-to-dc). In the communication mode, the first circuitry is configured as an inverter to convert direct current to alternating current (dc-to-ac).

[0005] The data exchanged between the dual mode wireless charging receiver and the secondary wireless power receiver is a function of secondary wireless power receiver type. When the secondary wireless power receiver powers-up based on the power received from the dual mode wireless charging receiver, it communicates its type amongst other information to the dual mode wireless charging receiver. Depending on the type of the secondary wireless power receiver, the dual mode wireless charging receiver's second circuitry is configured to send encrypted data and/or to decrypt the received data to and from the secondary wireless power receiver. In a first embodiment, when the secondary wireless power receiver is a non-authenticating secondary wireless power receiver, the dual mode wireless charging receiver receives and interprets the data from the non-authenticating secondary wireless power receiver without any authentication or encryption or decryption in a defined sequence as per the identified wireless power protocol. In a second embodiment, when the secondary wireless power receiver is a one-way authenticating secondary wireless power receiver, the dual mode wireless charging receiver: provides authentication information to the one-way authenticating secondary wireless power receiver to authenticate the dual mode wireless charging receiver, receives, decrypts and interprets the data from the one-way authenticating secondary wireless power receiver and responds with suitable encrypted data to the one-way authenticating secondary wireless power receiver in a defined sequence as per the identified wireless power protocol.

[0006] In a third embodiment, when the secondary wireless power receiver is a two-way authenticating secondary wireless power receiver, the dual mode wireless charging receiver: initiates exchange of the authentication information between the dual mode

wireless charging receiver and the two-way authenticating secondary wireless power receiver to authenticate the dual mode wireless charging receiver and the two-way authenticating secondary wireless power receiver, receives, decrypts and interprets data from the two-way authenticating secondary wireless power receiver and responds with suitable encrypted data to the two-way authenticating secondary wireless power receiver in a defined sequence as per the identified wireless power protocol. In a fourth embodiment, when the secondary wireless power receiver is a power sinking secondary wireless power receiver, the dual mode wireless charging receiver receives a request from the power sinking secondary wireless power receiver. The dual mode wireless charging receiver interprets the received request and performs a function associated with the transmitted power in conjunction with the first circuitry. For example, the dual mode wireless charging receiver interprets the request from the power sinking secondary wireless power receiver to perform a function such as increase the transmitted power, decrease the transmitted power, maintain the transmitted power, turn off the transmitted power, etc and takes action as per the wireless power protocol for such a type of secondary wireless power receiver.

[0007] Disclosed herein is also a method for delivering power from a dual mode wireless charging receiver to a secondary wireless power receiver and exchanging information between the dual mode wireless charging receiver and the secondary wireless power receiver. The method comprises steps to power-up, communicate, and charge the secondary wireless power receiver. A dual mode wireless charging receiver comprising a first circuitry and a second circuitry is provided. The first circuitry comprises an impedance network, a switch network, a filter capacitor, and one or more switches. The second circuitry comprises a security engine, a control logic circuit, and a modulator/demodulator circuit. The dual mode wireless charging receiver configures the first circuitry to receive the power from a wireless power transmitter. In the charging mode, the first circuitry, based on an input from the control logic circuit is configured by the dual mode wireless charging receiver to change the impedance of the impedance network and topology of the switch network to obtain a modified form of the received power, and apply the modified form of the power to the load device. In the

communication mode, the first circuitry is configured by the dual mode wireless charging receiver, based on an input from the control logic circuit, to change impedance of the impedance network and the topology of the switch network to transmit at least part of the power applied to the load device to the secondary wireless power receiver to power-up the secondary wireless power receiver. The dual mode wireless charging receiver configures the second circuitry to identify a type of the secondary wireless power receiver and a wireless power protocol of the secondary wireless power receiver. The dual mode wireless charging receiver then configures the security engine to authenticate, decrypt and encrypt a data transfer between the dual mode wireless charging receiver and the secondary wireless power receiver via the identified wireless power protocol.

[0008] Depending on the type of secondary wireless power receiver, the dual mode wireless charging receiver configures the second circuitry. If the secondary wireless power receiver is a non-authenticating secondary wireless power receiver, the second circuitry is configured to receive and interpret the data from the secondary wireless power receiver in the identified wireless power protocol without authentication and/or encryption. If the secondary wireless power receiver is a one-way authenticating secondary wireless power receiver, the second circuitry is configured to provide authentication information, in conjunction with the security engine, to the one-way authenticating secondary wireless power receiver to authenticate the dual mode wireless charging receiver, receive, decrypt and interpret the data from the one-way authenticating secondary wireless power receiver and respond with suitable encrypted data to the one-way authenticating secondary wireless power receiver in the identified wireless power protocol. If the secondary wireless power receiver is a two-way authenticating secondary wireless power receiver, the second circuitry is configured to initiate exchange of the authentication information between the dual mode wireless charging receiver and the two-way authenticating secondary wireless power receiver to authenticate the dual mode wireless charging receiver and the two-way authenticating secondary wireless power receiver, receive, decrypt and interpret the data from the two-way authenticating secondary wireless power receiver and respond with suitable encrypted data to the two-way authenticating secondary wireless power receiver in the identified wireless power

protocol. If the secondary wireless power receiver is a power sinking secondary wireless power receiver, the second circuitry on receiving a request from the secondary wireless power receiver, interprets the received request and performs a function associated with the transmitted power, in conjunction with the first circuitry. The function performed may include one of increase the transmitted power, decrease the transmitted power, maintain the transmitted power, turn off the transmitted power, etc., and takes action as per the wireless power protocol for such a type of secondary wireless power receiver.

[0009] The dual mode wireless charging receiver further checks the received data for errors and transmits the checked data and reapplies transmission of power on detection of errors in the received data. The dual mode wireless charging receiver then terminates the transmission of power on detecting an end of the received data or an end of the encrypted data or a timeout of a predetermined duration of power transmission time. The dual mode wireless charging receiver transmits a completion code on detection of the end of the received data or the end of the encrypted data or the timeout of a predetermined duration of power transmission time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing summary, as well as the following detailed description of the invention, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, exemplary constructions of the invention are shown in the drawings. However, the invention is not limited to the specific methods and components disclosed herein.

[0011] FIG. 1 exemplarily illustrates a schematic diagram of a dual mode wireless charging receiver.

[0012] FIG. 2A exemplarily illustrates a schematic diagram of a wireless power charging system, wherein a wireless power transmitter transmits wireless power to the

dual mode wireless charging receiver through a magnetic field using inductive coupling and through a electric field using capacitive coupling.

[0013] FIG. **2B** exemplarily illustrates a flow diagram showing the operation of the dual mode wireless charging receiver in a charging mode.

[0014] FIG. **3** exemplarily illustrates a schematic diagram showing the operation of the dual mode wireless charging receiver in a communication mode, wherein the dual mode wireless charging receiver is in communication with a secondary wireless power receiver.

[0015] FIGS. **4A-4D** exemplarily illustrate flow diagrams showing the operation of the dual mode wireless charging receiver in communication with a non-authenticating, a one-way authenticating, a two-way authenticating and a power sinking secondary wireless power receiver respectively.

[0016] FIG. **5A** exemplarily illustrates the schematic diagram of the dual mode wireless charging receiver in the charging mode.

[0017] FIG. **5B** exemplarily illustrates the schematic diagram of the dual mode wireless charging receiver in the communication mode.

[0018] FIG. **6A** exemplarily illustrates a switch network of the dual mode wireless charging receiver.

[0019] FIG. **6B** exemplarily illustrates an embodiment of the switch network of the dual mode wireless charging receiver in the charging mode.

[0020] FIG. **7A** exemplarily illustrates a first embodiment of the switch network of the dual mode wireless charging receiver in the communication mode.

[0021] FIG. 7B exemplarily illustrates a second embodiment of the switch network of the dual mode wireless charging receiver in the communication mode.

DETAILED DESCRIPTION OF THE INVENTION

[0022] FIG. 1 exemplarily illustrates a schematic diagram of a dual mode wireless charging receiver **100**. The dual mode wireless charging receiver **100** is typically integrated into a mobile device, for example, a mobile phone. The dual mode wireless charging receiver **100** operates in a charging mode or a communication mode. In charging mode, the dual mode wireless charging receiver **100** applies a modified form of received power to a load device. In communication mode, the dual mode wireless charging receiver **100** provides at least part of the modified power to a secondary wireless power receiver **300** exemplarily illustrated in FIG. 3, to enable the secondary wireless power receiver **300** to power up and start communicating with the dual mode wireless charging receiver **100**.

[0023] The dual mode wireless charging receiver **100** comprises a first circuitry and a second circuitry. The first circuitry and the second circuitry operate in charging mode on power-up. In the charging mode, the first circuitry receives power from a wireless power transmitter **200** and applies that power to the load device, for example, a battery, a resistive load, etc. The first circuitry comprises an impedance network **101**, a switch network **102**, a filter capacitor **107**, and switches S1 and S2. In the charging mode, the switch network **102** of the first circuitry is configured as a rectifier; switch S1 is open and switch S2 is closed to direct the rectified power to the load device, for example, a battery. In the communication mode, the switch network **102** of the first circuitry is configured as an inverter, transforming the dual mode wireless charging receiver **100** into a wireless power transmitter for transmitting power to a secondary wireless power receiver **300**. In the communication mode, switch S1 is closed and switch S2 is kept open to direct the power from the battery via the inverter to one of a coil or a capacitor. The coil or the capacitor is used to wirelessly transmit dual mode wireless charging receiver's **100** battery power to the secondary wireless power receiver **300** via a magnetic field or an

electric field. In the communication mode, when the secondary wireless power receiver **300** powers-up based on the power received from the dual mode wireless charging receiver **100**, the secondary wireless power receiver **300** communicates its type amongst other information. The second circuitry comprises a control logic circuit **105**, a security engine **104**, and a modulator/demodulator circuit **103**. In the communication mode, the second circuitry of the dual mode wireless charging receiver **100** interprets the communicated information received from the secondary wireless power receiver **300**. On detection of the secondary wireless power receiver type, the second circuitry automatically adapts to the wireless power protocol based on the type of the secondary wireless power receiver **300**.

[0024] The impedance network **101** comprises one or more of passive electronic components, for example, a resistor, a capacitor, a magnetic device, a transducer, transformer etc.; active electronic components, for example, a diode, a transistor such as a metal oxide semiconductor field effect transistor (MOSFET), a bipolar transistor, etc., operational amplifiers, an optoelectronic device, etc., and electronic switches. These electronic components in combination are utilized to vary impedance of the dual mode wireless charging receiver **100** prior to transmitting power to a secondary wireless power receiver **300**.

[0025] The control logic circuit **105** is, for example, a state machine, a microcontroller, etc. The control logic circuit **105** is configured to provide a pulse width modulated (PWM) signal to the first circuitry. The security engine **104** contains authentication, encryption and decryption functions ensuring the data exchange between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300** remains secure. The security engine **104** is configured to authenticate the secondary wireless charging receiver **300**, decrypt and encrypt a data transfer between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300** as per the identified wireless power protocol based on the type of the secondary wireless power receiver **300**. The authentication process may be one-way or mutual depending on the type of secondary wireless power receiver **300**.

[0026] The second circuitry enables the dual mode wireless charging receiver **100** to have either a one-way or a two-way communication with the secondary wireless power receiver **300**, based on the type and capabilities of the secondary wireless power receiver **300**. The second circuitry also enables the dual mode wireless charging receiver **100** to have either a one-way or a two-way communication with the wireless power transmitter **200**. Based on the secondary wireless power receiver **300**, the second circuitry is configured to perform one of (a) receive and interpret the data from the secondary wireless power receiver **300** in the identified wireless power protocol; (b) provide authentication information to the secondary wireless power receiver **300** to authenticate the dual mode wireless charging receiver **100**, receive, decrypt and interpret the data from the secondary wireless power receiver **300** and respond with suitable encrypted data to the secondary wireless power receiver **300** in the identified wireless power protocol; (c) initiate exchange of the authentication information between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300** to authenticate the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**, receive, decrypt and interpret the data from the secondary wireless power receiver **300** and respond with suitable encrypted data to the secondary wireless power receiver **300** in the identified wireless power protocol; or (d) receive a request from the secondary wireless power receiver **300**, interpret the request and perform a function associated with the transmitted power, in conjunction with the first circuitry. The functions performed may include one of increase the transmitted power, decrease the transmitted power, maintain the transmitted power, turn off the transmitted power, etc., and takes action as per the wireless power protocol for such a type of secondary wireless power receiver.

[0027] FIG. 2A exemplarily illustrates a schematic diagram of a wireless power charging system, wherein a wireless power transmitter **200** transmits wireless power to the dual mode wireless charging receiver **100** through a magnetic field using inductive coupling and through an electric field using capacitive coupling. In FIG. 2A, the wireless power transmitted to the dual mode wireless charging receiver **100** is magnetic field based or electric field based using inductive coupling or capacitive coupling respectively.

The transmitter coil **201** of the wireless power transmitter **200** is configured to wirelessly transmit power to the dual mode wireless charging receiver **100**. The transmitter coil **201** is used for inducing a magnetic field to a coupling region for providing energy transfer to the dual mode wireless charging receiver **100**. The wireless power transmitter **200** transmits power to the dual mode wireless charging receiver **100** by emanating the magnetic field using the transmitter coil **201**. The dual mode wireless charging receiver **100** comprises a receiver coil **106** that picks up the magnetic field with a certain coupling coefficient that exists between the transmitter coil **201** and the receiver coil **106**.

[0028] The wireless power transmitted to the dual mode wireless charging receiver **100** is electric field based using capacitive coupling existing between the capacitor **202** of the wireless power transmitter **200** and the capacitor **203** of the dual mode wireless charging receiver **100**. The capacitor **202** of the wireless power transmitter **200** is configured to wirelessly transmit power to the dual mode wireless charging receiver **100**. The capacitor **202** is used for inducing an electric field to a coupling region for providing energy transfer to the dual mode wireless charging receiver **100**. The wireless power transmitter **200** transmits power to the dual mode wireless charging receiver **100** by emanating the electric field using the capacitor **202**. The capacitor **203** of the dual mode wireless charging receiver **100** picks up the electric field with a certain coupling coefficient that exists between the capacitor **202** of the wireless power transmitter **200** and the capacitor **203** of the dual mode wireless charging receiver **100**.

[0029] FIG. **2B** exemplarily illustrates a flow diagram showing the operation of the dual mode wireless charging receiver **100** in the charging mode. In the charging mode, the dual mode wireless charging receiver **100** charges a load device, for example, a battery, other type of load, etc., that is connected to it. In the charging mode, switch S2 is closed and switch S1 is open to direct the rectified power to the load device. Based on an input from the control logic circuit **105**, the dual mode wireless charging receiver **100** changes impedance of the impedance network **101** and changes the topology of the switch network **102** to configure the first circuitry as a rectifier on receiving power from the wireless power transmitter **200**. The dual mode wireless charging receiver **100** powers

up and adjusts the impedance network **101** of the first circuitry. The dual mode wireless charging receiver **100** then enters a charging mode and starts communicating with the wireless power transmitter **200**. A power contract is then established between the dual mode wireless charging receiver **100** and the wireless power transmitter **200** and the dual mode wireless charging receiver **100** starts transferring the power to its load device, for example, a battery.

[0030] FIG. 3 exemplarily illustrates a schematic diagram showing the operation of the dual mode wireless charging receiver **100** in the communication mode, wherein the dual mode wireless charging receiver **100** as disclosed in the detailed description of FIG. 1 is in communication with a secondary wireless power receiver **300**. In the communication mode, switch S1 is closed and switch S2 is open to direct, for example, a battery's power via the switch network **102** to a coil or a capacitor and emanate power via a magnetic field or an electric field, respectively. In the communication mode, the dual mode wireless charging receiver **100** provides power to the secondary wireless power receiver **300** to enable the secondary wireless power receiver **300** to power up and start communicating as disclosed in the detailed description of FIGS. 4A-4D with the dual mode wireless charging receiver **100**. The dual mode wireless charging receiver **100** configures the switch network **102** of the first circuitry, as an inverter in the communication mode, transforming the dual mode wireless charging receiver **100** into a wireless power transmitter for transmitting power to the secondary wireless power receiver **300**.

[0031] FIGS. 4A-4D exemplarily illustrate flow diagrams showing the operation of the dual mode wireless charging receiver **100** in communication with a non-authenticating, a one-way authenticating, a two-way authenticating and a power sinking secondary wireless power receiver **300** respectively.

[0032] FIG. 4A exemplarily illustrates a flow diagram showing the operation of the dual mode wireless charging receiver **100** in communication with a non-authenticating secondary wireless power receiver **300**. The information exchanged between the

secondary wireless power receiver **300** and the dual mode wireless charging receiver **100** is a function of the secondary wireless power receiver **300** type. A non-authenticating secondary wireless power receiver **300** is used for applications such as a product advertisement in a retail store, a show promotion via a poster, etc. In these applications, the secondary wireless power receiver **300** used would be very undemanding. The first circuitry of the dual mode wireless charging receiver **100** is configured to change the impedance of the impedance network **101** and change the topology of the switch network **102** to transmit at least part of the modified power to the secondary wireless power receiver **300** to power-up the secondary wireless power receiver **300**. The modified power is, for example, stored in a battery. The second circuitry of the dual mode wireless charging receiver **100** is configured to identify a type of the secondary wireless power receiver **300** and identify a wireless power protocol of the secondary wireless power receiver **300**.

[0033] The secondary wireless power receiver **300** broadcasts its embedded information such as a product specific code, manufacturer code, website address, etc., which is recorded by the dual mode wireless charging receiver **100**. The secondary wireless power receiver **300** is a non-authenticating type of device, that is, the secondary wireless power receiver **300** does not seek to discover the identity of the dual mode wireless charging receiver **100**. The communication link established from the secondary wireless power receiver **300** to dual mode wireless charging receiver **100** is one-way and the secondary wireless power receiver **300** lacks the intelligence to perform any dual mode wireless charging receiver **100** requested services.

[0034] The dual mode wireless charging receiver **100** is instructed to enter “communication mode” and provide power by, for example, a software application that is resident and executing on a mobile device of the dual mode wireless charging receiver **100**. In an embodiment, the dual mode wireless charging receiver **100** is instructed to provide power by an external switch such as a hardware switch. When a communication mode is established between the dual mode wireless charging receiver **100** and the

secondary wireless power receiver **300**, the dual mode wireless charging receiver **100** identifies that the secondary wireless power receiver **300** is a non-authenticating secondary wireless power receiver **300**. The dual mode wireless charging receiver **100** maintains power until a predetermined amount of time or until it receives the “end of service” message whichever is the earliest. The dual mode wireless charging receiver **100** receives, interprets and records data sent by the secondary wireless power receiver **300** while providing power to the secondary wireless power receiver **300**. The received data is then error-checked and passed to the software application. The dual mode wireless charging receiver **100** reapplies the transmission of power on detection of errors in the received data. The software application disassembles the information and performs data specific functions, for example, routes the data to a website, retrieves and displays product specific content such as its price, ingredients, nutrient value, etc., entertainment poster specific content such as show times, locations, reviews, etc., and anything else as triggered by the data from secondary wireless power receiver **300**.

[0035] The non-authenticating secondary wireless power receiver **300** draws power only for communication with the dual mode wireless charging receiver **100**, that is, power is not drawn for charging, for example, a battery, a capacitor, other loads, etc. As a result, the power drain on the dual mode wireless charging receiver **100** is minimal.

[0036] FIG. **4B** exemplarily illustrates a flow diagram showing the operation of the dual mode wireless charging receiver **100** in communication with a one-way authenticating secondary wireless power receiver **300**. The secondary wireless power receiver **300** is a one-way authenticating type of device, that is, a source authenticating type of device. The first circuitry based on the input from the control logic circuit **105** of the dual mode wireless charging receiver **100** is configured to change the topology of the switch network **102** and the impedance of the impedance network to transmit at least part of the modified power to the secondary wireless power receiver **300** to power-up the secondary wireless power receiver **300**. The modified power is, for example, stored in a battery. The second circuitry of the dual mode wireless charging receiver **100** is configured to identify a type of the secondary wireless power receiver **300** and identify a

wireless power protocol of the secondary wireless power receiver **300**. The secondary wireless power receiver **300** then queries the dual mode wireless charging receiver **100** for authentication information.

[0037] When a communication mode is established between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**, the dual mode wireless charging receiver **100** identifies that the secondary wireless power receiver **300** is a one-way authenticating secondary wireless power receiver **300**. The dual mode wireless charging receiver **100** provides authentication information to the secondary wireless power receiver **300**. Based on the authentication information provided by the dual mode wireless charging receiver **100**, if the dual mode wireless charging receiver **100** is recognized as a known trusted source, the secondary wireless power receiver **300** requests the dual mode wireless charging receiver **100** of the service to be performed. The secondary wireless power receiver **300** receives and interprets the requested service and if the dual mode wireless charging receiver **100** is authorized for such a service, the secondary wireless power receiver **300** performs the requested service. The dual mode wireless charging receiver **100** configures the security engine **104** of the second circuitry to authenticate, decrypt and encrypt a data transfer between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300** and respond with suitable encrypted data to the secondary wireless power receiver **300** via the identified wireless power protocol. The dual mode wireless charging receiver **100** checks the received data for errors and transmits the checked data and reapplies transmission of power on detection of errors in the received data. The secondary wireless power receiver **300** then responds back with an “end of service” message containing, for example, a “done” completion code in the message. If the dual mode wireless charging receiver **100** fails authentication, that is, the dual mode wireless charging receiver **100** is not a trusted source, not authorized for the requested service, the secondary wireless power receiver **300** sends an “end of service” message containing, for example, an “error” completion code in the message.

[0038] The dual mode wireless charging receiver **100** is instructed to enter “communication mode” and provide power by, for example, a software application that is resident and executing on the mobile device of the dual mode wireless charging receiver **100**. In an embodiment, the dual mode wireless charging receiver **100** is instructed to provide power by an external switch such as a hardware switch. The dual mode wireless charging receiver **100** provides power to the secondary wireless power receiver **300** for a predetermined amount of time or until it receives the “end of service” message whichever is the earliest. The dual mode wireless charging receiver **100** provides its specific authentication information in the defined sequences as per the wireless power protocol based on the type of the secondary wireless power receiver **300**. In an embodiment, the dual mode wireless charging receiver **100** generates the authentication information in conjunction with the software application. The dual mode wireless charging receiver **100** provides the service of interest as informed by the application. The software application disassembles the messages from the secondary wireless power receiver **300** and responds with the additional information, for example, unlocking a computer requires additional information such as login information, password information are sent as instructed by the software application to the secondary wireless power receiver **300**.

[0039] FIG. 4C exemplarily illustrates a flow diagram showing the operation of the dual mode wireless charging receiver **100** in communication with a two-way authenticating secondary wireless power receiver **300**. The first circuitry based on an input from the control logic circuit **105** of the dual mode wireless charging receiver **100** is configured to change the topology of the switch network **102** and the impedance of the impedance network **101** to transmit at least part of the modified power to the secondary wireless power receiver **300** to power-up the secondary wireless power receiver **300**. The modified power is, for example, stored in a battery. The second circuitry of the dual mode wireless charging receiver **100** is configured to identify a type of the secondary wireless power receiver **300** and identify a wireless power protocol of the secondary wireless power receiver **300**. When a communication mode is established between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**, a mutual authentication process between the dual mode wireless charging receiver **100** and the

secondary wireless power receiver **300** is established. The second circuitry of the dual mode wireless charging receiver **100** initiates exchange of the authentication information between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**, to authenticate the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**, receives, decrypts and interprets the data from the secondary wireless power receiver **300** and respond with suitable encrypted data to the secondary wireless power receiver **300** in the identified wireless power protocol. The dual mode wireless charging receiver **100** configures the security engine **104** of the second circuitry to authenticate, decrypt and encrypt a data transfer between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300** via the identified wireless power protocol. The dual mode wireless charging receiver **100** transmits a completion code on detection of the end of the received data or the timeout of a predetermined duration of power transmission time.

[0040] For example, in scenarios such as purchasing an item from a vending machine, purchasing a newspaper, purchasing bus tickets, using a travel-Pass, withdrawing money from an automated teller (ATM) machine, a two-way authentication is preferred between the secondary wireless power receiver **300** and dual mode wireless charging receiver **100**. The higher level software applications in both the secondary wireless power receiver **300** and the dual mode wireless charging receiver **100** drive the mutual authentication process. The dual mode wireless charging receiver **100** authenticates the secondary wireless power receiver **300** to ensure the veracity of the machine placed in public domain. The power drawn from the dual mode wireless charging receiver **100** by the secondary wireless power receiver **300** is only for two-way communication. As a result, the power drain on the dual mode wireless charging receiver **100** is minimal.

[0041] FIG. **4D** exemplarily illustrates a flow diagram showing the operation of the dual mode wireless charging receiver **100** in communication with a power sinking secondary wireless power receiver **300**. The power from the dual mode wireless charging receiver **100** is not only used for communication but also for low power services such as battery charging. Consider an example, where a first mobile device, for example, a dual

mode wireless charging receiver **100** provides wireless power to charge a second mobile device's battery, for example, a secondary wireless power receiver's **300** battery. The first circuitry based on the input from the control logic circuit **105** of the dual mode wireless charging receiver **100** is configured to change the topology of the switch network **102** and the impedance of the impedance network **101** to transmit at least part of the modified power to the secondary wireless power receiver **300** to power-up the secondary wireless power receiver **300**. The modified power is, for example, stored in a battery. The second circuitry of the dual mode wireless charging receiver **100** is configured to identify a type of the secondary wireless power receiver **300** and identify a wireless power protocol of the secondary wireless power receiver **300**. A communication mode is established between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**. The dual mode wireless charging receiver **100** identifies that the secondary wireless power receiver **300** is a power sinking secondary wireless power receiver **300**. An authentication process is generally not requested by the power sinking secondary wireless power receiver **300**. The communication of secondary wireless power receiver **300** with the dual mode wireless charging receiver **100** is independent of the state of its mobile device's battery. When power is received from the dual mode wireless charging receiver **100**, secondary wireless power receiver **300** communicates and provides feedback to perform a function associated with the transmitted power, in conjunction with the first circuitry. The functions performed by the dual mode wireless charging receiver **100** may include one of increase the transmitted power, decrease the transmitted power, maintain the transmitted power, turnoff the transmitted power, etc. The dual mode wireless charging receiver **100** takes action as per the wireless power protocol for such a type of secondary wireless power receiver. As the dual mode wireless charging receiver's **100** available power is used to power up the secondary wireless power receiver **300** for communication and for charging the secondary wireless power receiver's **300** battery, the power drain is at its maximum.

[0042] FIG. 5A exemplarily illustrates the schematic diagram of the dual mode wireless charging receiver **100** in the charging mode. The dual mode wireless charging receiver **100** as exemplarily illustrated in the detailed description of FIG. 1 configures the switch

network **102** of the first circuitry, as a rectifier in the charging mode. In the charging mode, a S2 switch is closed and a S1 switch is open. The configuration of S2 switch and S1 switch drives to deliver power from the dual mode wireless charging receiver **100** to the secondary wireless power receiver **300**.

[0043] FIG. **5B** exemplarily illustrates the schematic diagram of the dual mode wireless charging receiver **100** in the communication mode. The dual mode wireless charging receiver **100** as exemplarily illustrated in the detailed description of FIG. **1** configures the switch network **102** of the first circuitry, as an inverter in the communication mode. In the communication mode, a S1 switch is closed and a S2 switch is open. The configuration of S2 switch and S1 switch drives to establish a communication link between the dual mode wireless charging receiver **100** and the secondary wireless power receiver **300**.

[0044] FIG. **6A** exemplarily illustrates the switch network **102** of the dual mode wireless charging receiver **100**. The switch network **102** comprises switches S1a, S1b, S3a, S3b, S2, and S4. The switch network **102** is configured as an inverter or a rectifier depending on the mode of operation of the dual mode wireless charging receiver **100**.

[0045] FIG. **6B** exemplarily illustrates an embodiment of the switch network **102** of the dual mode wireless charging receiver **100** in the charging mode. The switch network **102** as exemplarily illustrated in FIG. **6B** is configured as a full wave rectifier, for example, a full synchronous full wave rectifier by keeping Vbat path off and keeping switches S1a and S3a in an off state. Switches S1b, S2, S3b, and S4 are driven with the timing relationship as exemplarily illustrated in FIG. **6B** in full synchronous full wave rectification mode. In an embodiment, switches S1b, S2, S3b, and S4 are driven in half synchronous full wave rectification mode.

[0046] FIG. **7A** exemplarily illustrates a first embodiment of the switch network **102** of the dual mode wireless charging receiver **100** in the communication mode. In the communication mode, the switch network **102** can be configured as a full bridge inverter

by keeping switches S1a, S1b and S4 in an on state and switches S3a, S3b and S2 in an off state or by keeping switches S3a, S3b and S2 in an on state and switches S1a, S1b and S4 in an off state of the switch network **102**, exemplarily illustrated by the timing relationship waveform in FIG. **7A**.

[0047] FIG. **7B** exemplarily illustrates a second embodiment of the switch network **102** of the dual mode wireless charging receiver **100** in the communication mode. The switch network **102** is configured as half bridge inverter by keeping switches S3a and S3b in an off state and S4 in an on state of the switch network **102** exemplarily illustrated in FIG. **6A**. Switches S1a, S1b and S2 are driven with the timing relationship as exemplarily illustrated in FIG. **7B**. Alternatively the switch network **102** is configured as a half bridge inverter by keeping switches S2 in an on state and switches S1a and S1b in an off state of the switch network **102** exemplarily illustrated in FIG. **6A**.

[0048] The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials, and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may affect numerous modifications thereto and changes may be made without departing from the scope and spirit of the invention in its aspects.

CLAIMS

We claim:

1. A dual mode wireless charging receiver configured to selectively apply a received power to a load device and utilize at least a part of said power to power-up, communicate, and charge a secondary wireless power receiver, said dual mode wireless charging receiver comprising:

a first circuitry comprising:

an impedance network;

a switch network;

a filter capacitor; and one or more switches;

a second circuitry comprising:

a security engine configured to authenticate, decrypt and encrypt a data transfer between said dual mode wireless charging receiver and said secondary wireless power receiver;

a control logic circuit; and

a modulator/demodulator circuit;

said first circuitry configured to receive said power from a wireless power transmitter;

said first circuitry, based on an input from said control logic circuit, configured to change impedance of said impedance network and topology of said switch network to obtain a modified form of said received power, and apply said modified form of said power to said load device;

said first circuitry, based on an input from said control logic circuit, configured to change said topology of said switch network and said impedance of said impedance network to transmit at least part of said modified power to said secondary wireless power receiver to power-up said secondary wireless power receiver;

said second circuitry configured to identify a type of said secondary wireless power receiver and identify a wireless power protocol of said secondary wireless power receiver;

said second circuitry, on power-up of said secondary wireless power receiver, configured to perform one of:

receiving and interpreting said data from said secondary wireless power receiver in said identified wireless power protocol;

providing authentication information to said secondary wireless power receiver to authenticate said dual mode wireless charging receiver, receive and interpret said data from said secondary wireless power receiver and respond with suitable encrypted data to secondary wireless power receiver in said identified wireless power protocol;

initiating exchange of said authentication information between said dual mode wireless charging receiver and said secondary wireless power receiver, to authenticate said dual mode wireless charging receiver and said secondary wireless power receiver, receive, decrypt and interpret said

data from said secondary wireless power receiver and respond with said encrypted data to secondary wireless power receiver in said identified wireless power protocol; and

receiving and interpreting a request from said secondary wireless power receiver and performing a function associated with said transmitted power in conjunction with said first circuitry.

2. The dual mode wireless charging receiver of claim 1, wherein said first circuitry is configured as one of an inverter and a rectifier.
3. A method for delivering power from a dual mode wireless charging receiver to a secondary wireless power receiver and exchanging information between the dual mode wireless charging receiver and the secondary wireless power receiver, to power-up, communicate, and charge said secondary wireless power receiver, said method comprising:

providing said dual mode wireless charging receiver comprising:

a first circuitry comprising an impedance network, a switch network, a filter capacitor, and one or more switches; and

a second circuitry, said second circuitry comprising a security engine, and a modulator/demodulator circuit;

configuring said first circuitry to receive said power from a wireless power transmitter;

configuring said first circuitry to change impedance of said impedance network and topology of said switch network to obtain a modified form of said received power, and apply said modified form of said power to said load device;

configuring said first circuitry to change impedance of said impedance network and said topology of said switch network to transmit at least part of said power to said secondary wireless power receiver to power-up said secondary wireless power receiver;

configuring said second circuitry to identify a type of said secondary wireless power receiver and a wireless power protocol of said secondary wireless power receiver;

configuring said security engine to authenticate, decrypt and encrypt a data transfer between said dual mode wireless charging receiver and said secondary wireless power receiver via said identified wireless power protocol;

configuring said second circuitry for performing one of:

- receiving and interpreting said data from said secondary wireless power receiver in said identified wireless power protocol;

- providing authentication information to said secondary wireless power receiver to authenticate said dual mode wireless charging receiver, receive, decrypt and interpret said data from said secondary wireless power receiver and respond with suitable encrypted data to secondary wireless power receiver in said identified wireless power protocol;

- initiating exchange of said authentication information between said dual mode wireless charging receiver and said secondary wireless power receiver, to authenticate said dual mode wireless charging receiver and said secondary wireless power receiver, receive, decrypt and interpret said data from said secondary wireless power receiver and respond with said

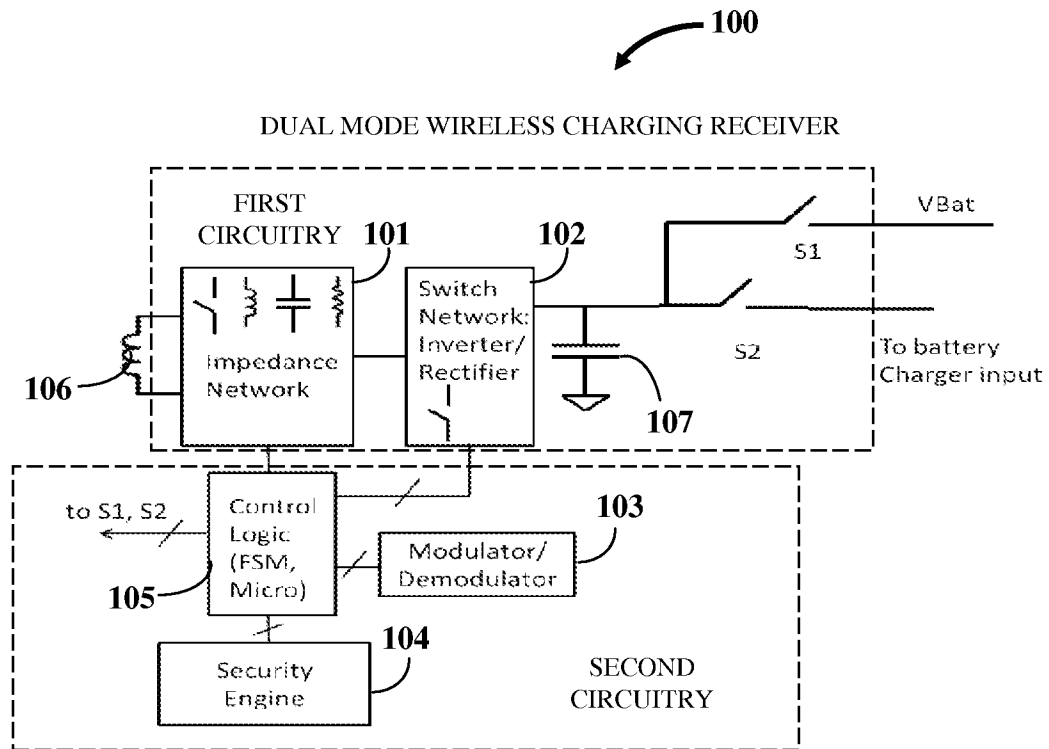
encrypted data to secondary wireless power receiver in said identified wireless power protocol; and

receiving and interpreting a request from said secondary wireless power receiver and performing a function associated with said transmitted power in conjunction with said first circuitry.

4. The method of claim 3, further comprising configuring said first circuitry as one of an inverter and a rectifier, and adjusting said impedance of said impedance network in said first circuitry by said dual mode wireless charging receiver.
5. The method of claim 3, further comprising terminating said transmission of said power on detecting one of an end of said received data, an end of said encrypted data and a timeout of a predetermined duration of power transmission time.
6. The method of claim 3, further comprising checking said received data for errors and transmitting said checked data and reapplying said transmission of said power on detection of said errors in said received data.
7. The method of claim 3, further comprising transmitting a completion code on said detection of one of said end of said received data, said end of said encrypted data and said timeout of a predetermined duration of power transmission time by said dual mode wireless charging receiver.

ABSTRACT

A dual mode wireless charging receiver (DMWCR) selectively applying a received power to a load device and utilizing at least a part of the power to power-up, communicate, and charge a secondary wireless power receiver (SWPR) is provided. The DMWCR includes a first circuitry having an impedance network, a switch network, a filter capacitor, and one or more switches, and a second circuitry having a security engine, a control logic circuit, and a modulator/demodulator circuit. The first circuitry receives power in charging mode and transmits power in communication mode. The second circuitry configures the first circuitry to allow receipt and transmittal of power, receives and interprets data from SWPR in identified wireless power protocol, and based on the type of SWPR authenticates, decrypts and encrypts data transfer between DMWCR and SWPR, and receives and executes on a request from SWPR to perform a function associated with transmitted power.

**FIG. 1**

Dual Mode Wireless Charging Receiver in "Charging Mode"

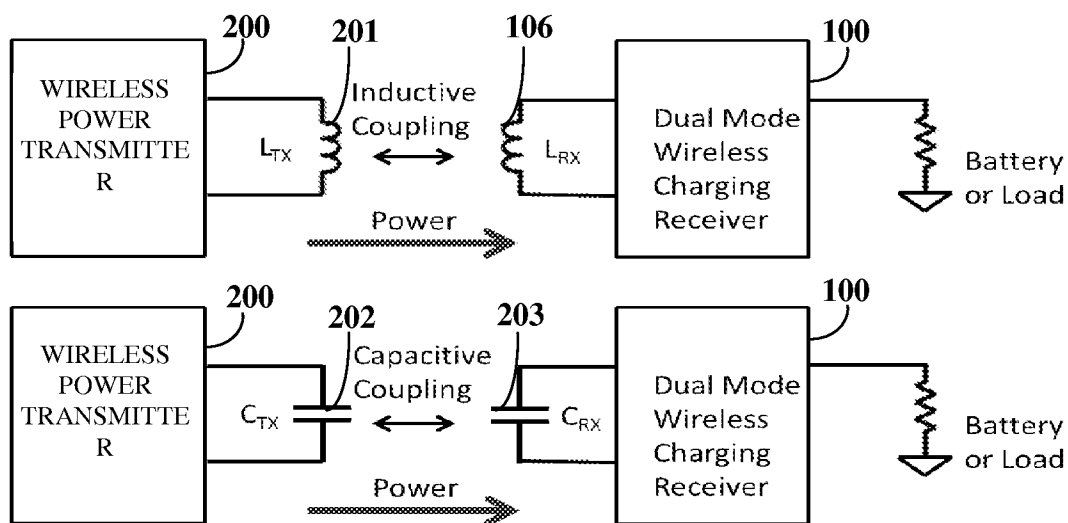


FIG. 2A

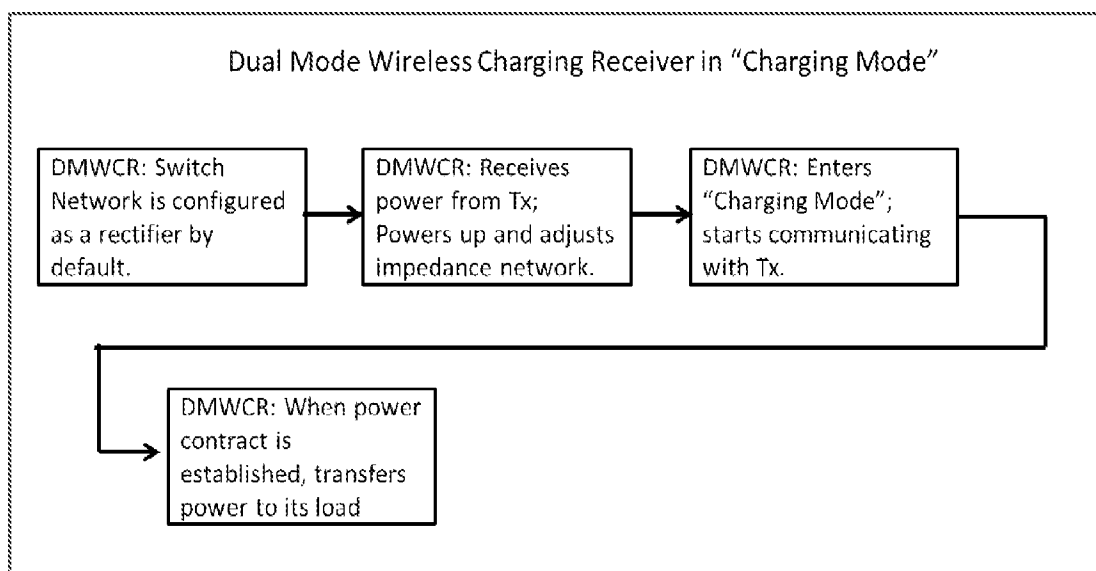


FIG. 2B

Dual Mode Wireless Charging Receiver in “Communication Mode”

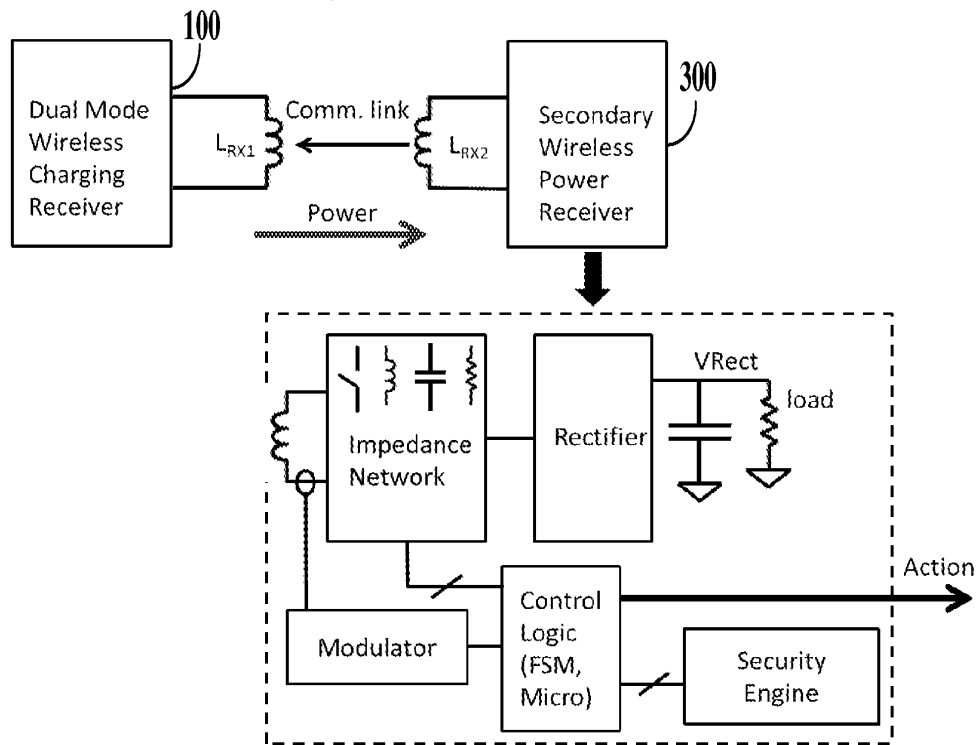


FIG. 3

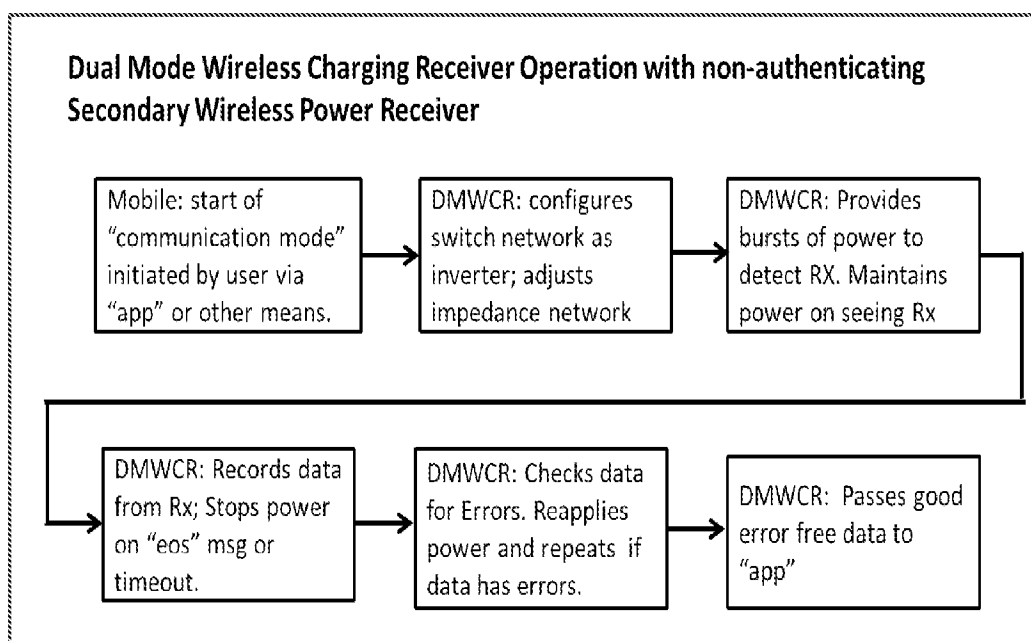


FIG. 4A

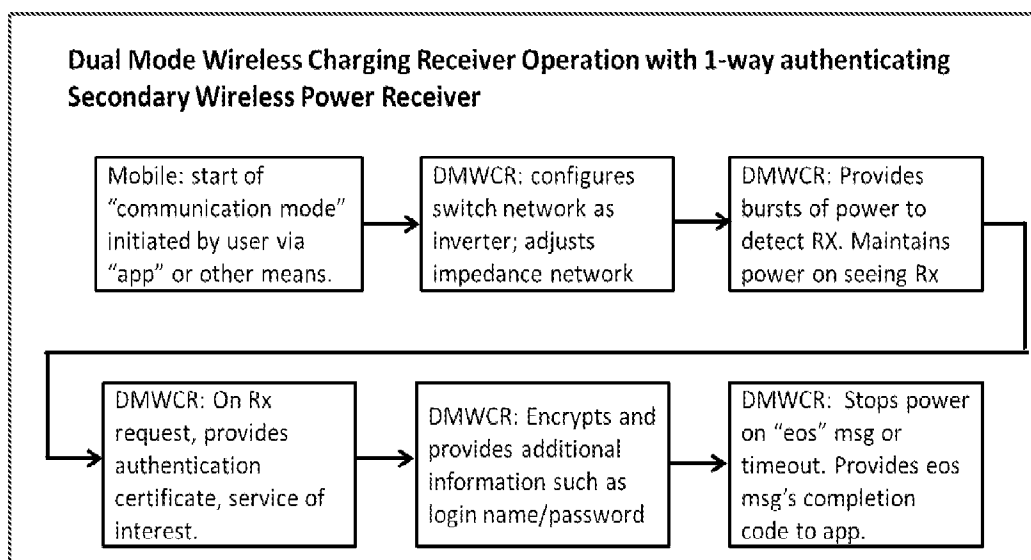


FIG. 4B

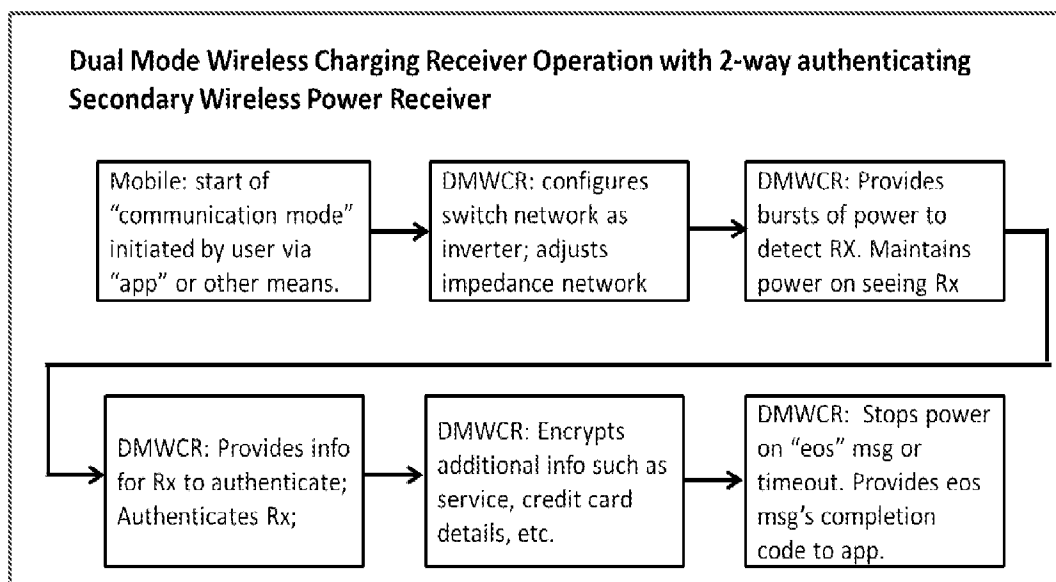


FIG. 4C

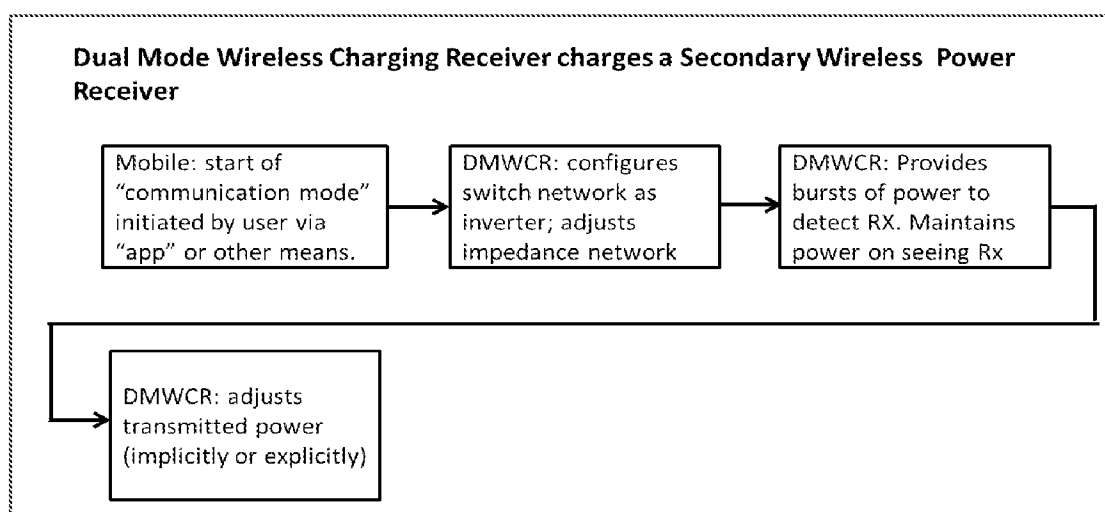


FIG. 4D

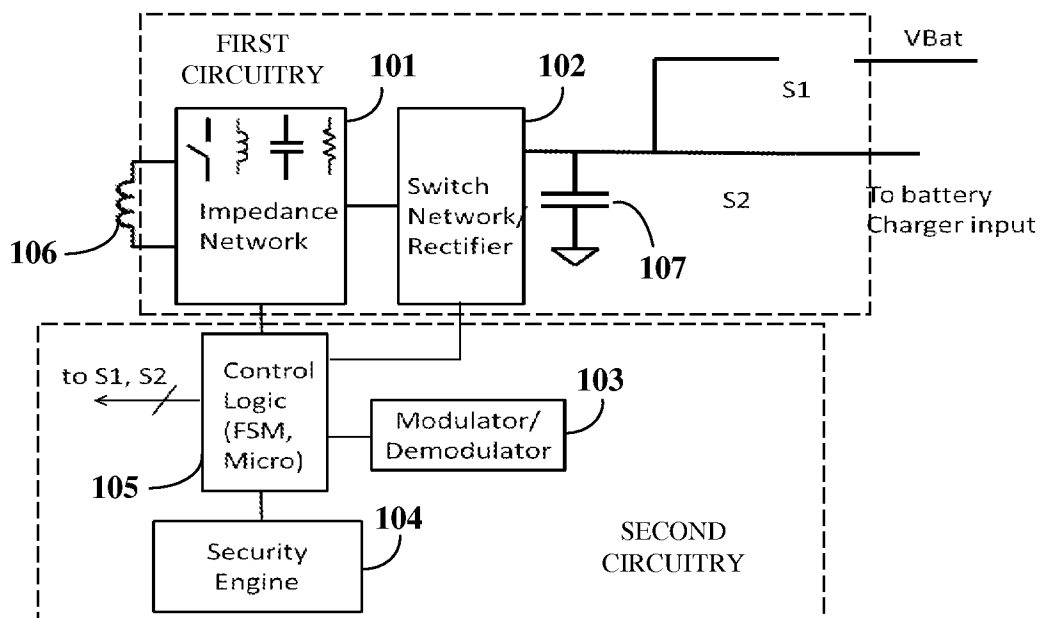


FIG. 5A

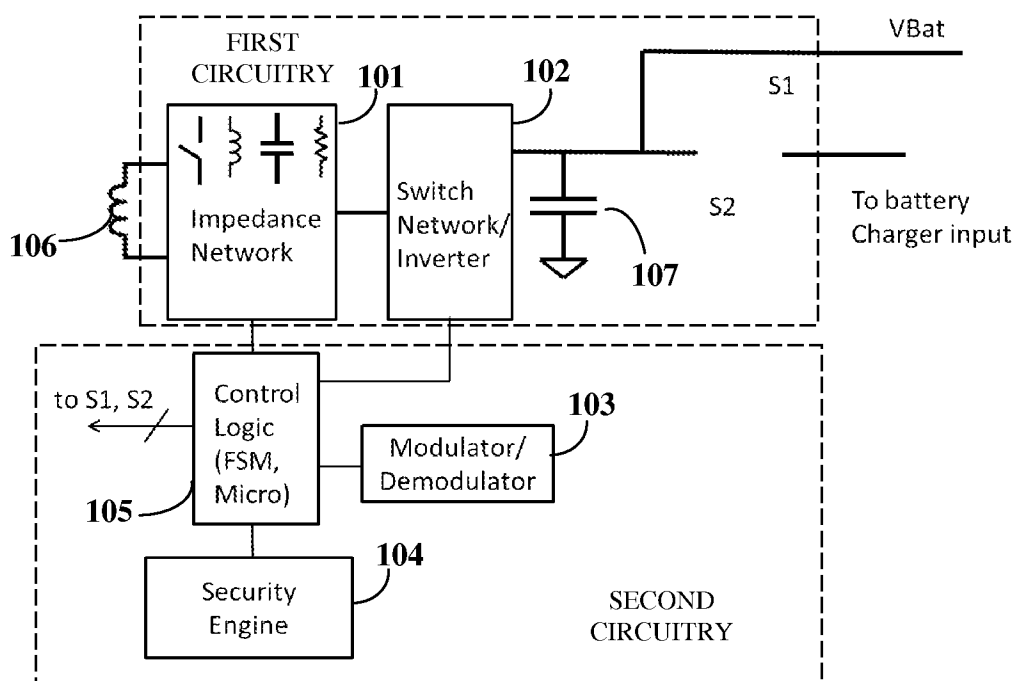


FIG. 5B

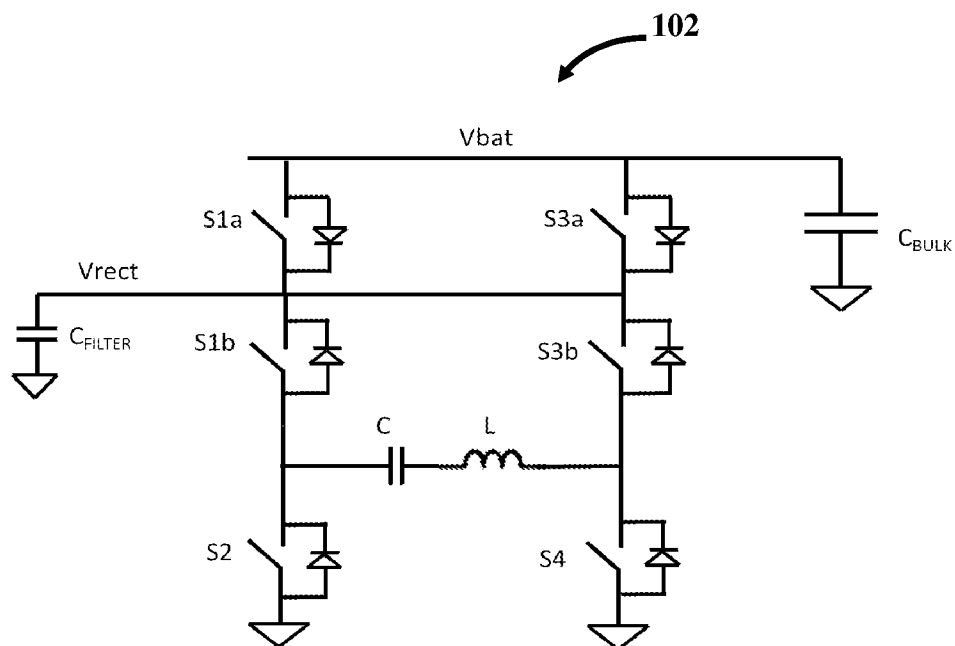


FIG. 6A

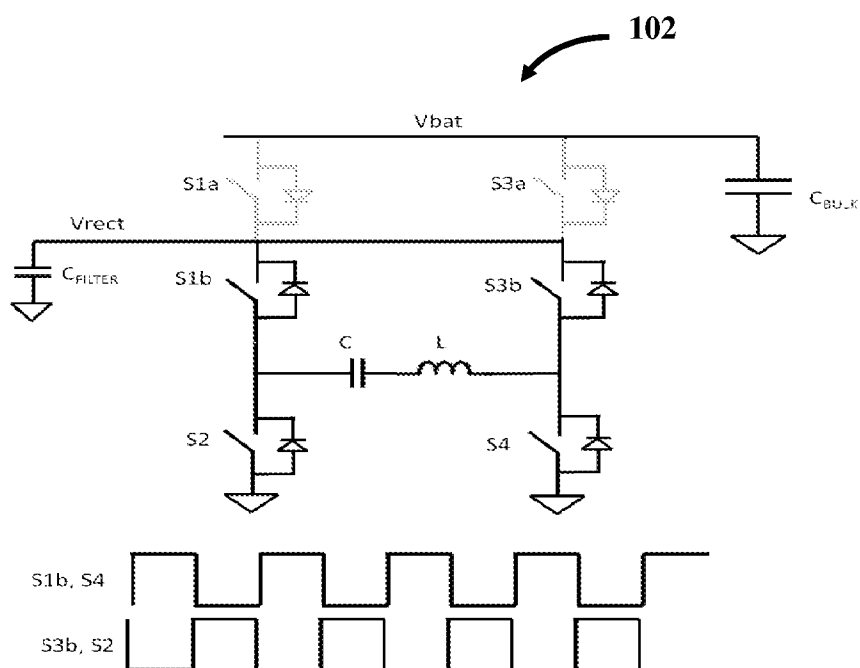


FIG. 6B

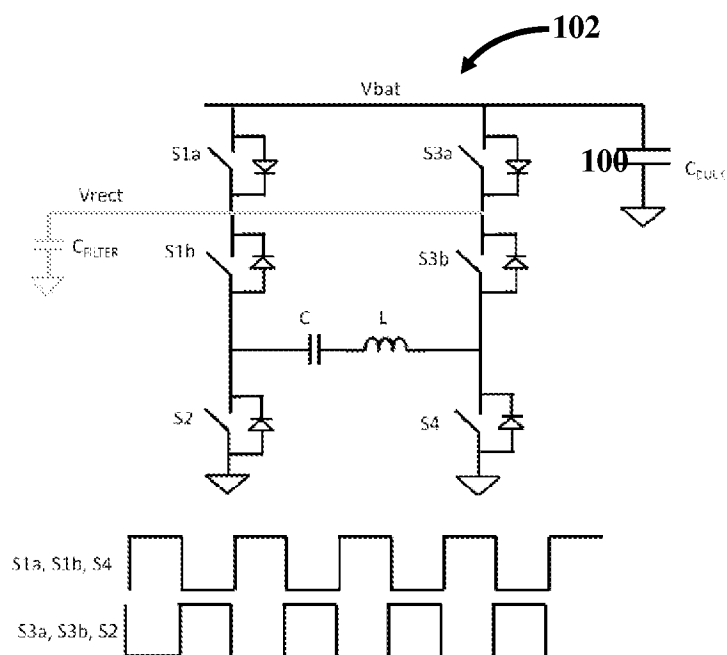


FIG. 7A

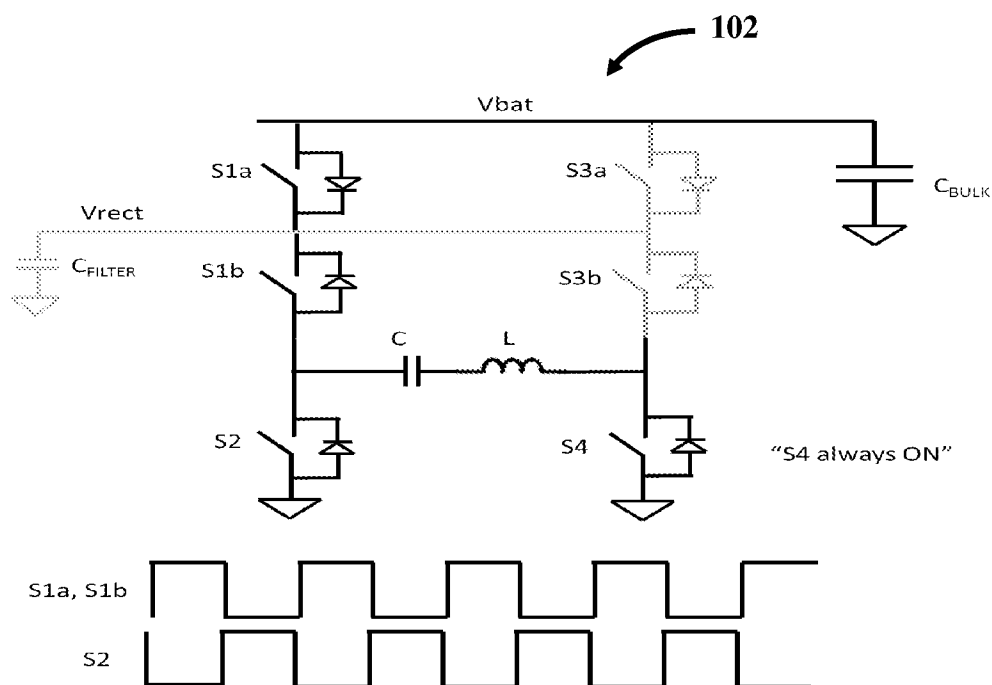


FIG. 7B