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(54) **MULTI-MODE RFID READER ARCHITECTURE**

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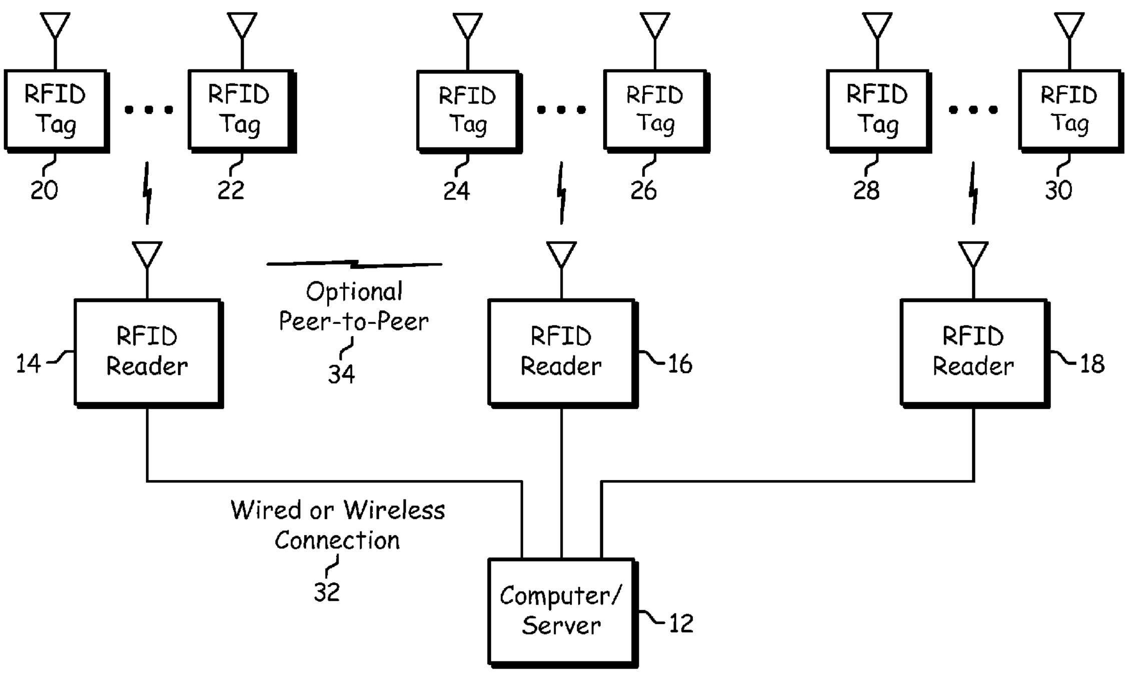
(57) **ABSTRACT**

A multi-mode RFID reader operates in both far field mode and near field mode. The multi-mode RFID reader includes a transmitter section, a receiver section, a transmit multiplexer and a receive multiplexer. Both the transmit multiplexer and the receive multiplexer are configurably coupled to a far field antenna structure and a near field coil structure. For far field operation, the transmit multiplexer provides an up-converted outbound signal to a far field antenna structure and the receive multiplexer provides an inbound signal to a receiver section. For near field operation, the transmit multiplexer provides an up-converted outbound signal to the near field coil structure and the receive multiplexer provides an inbound signal to the receiver section.



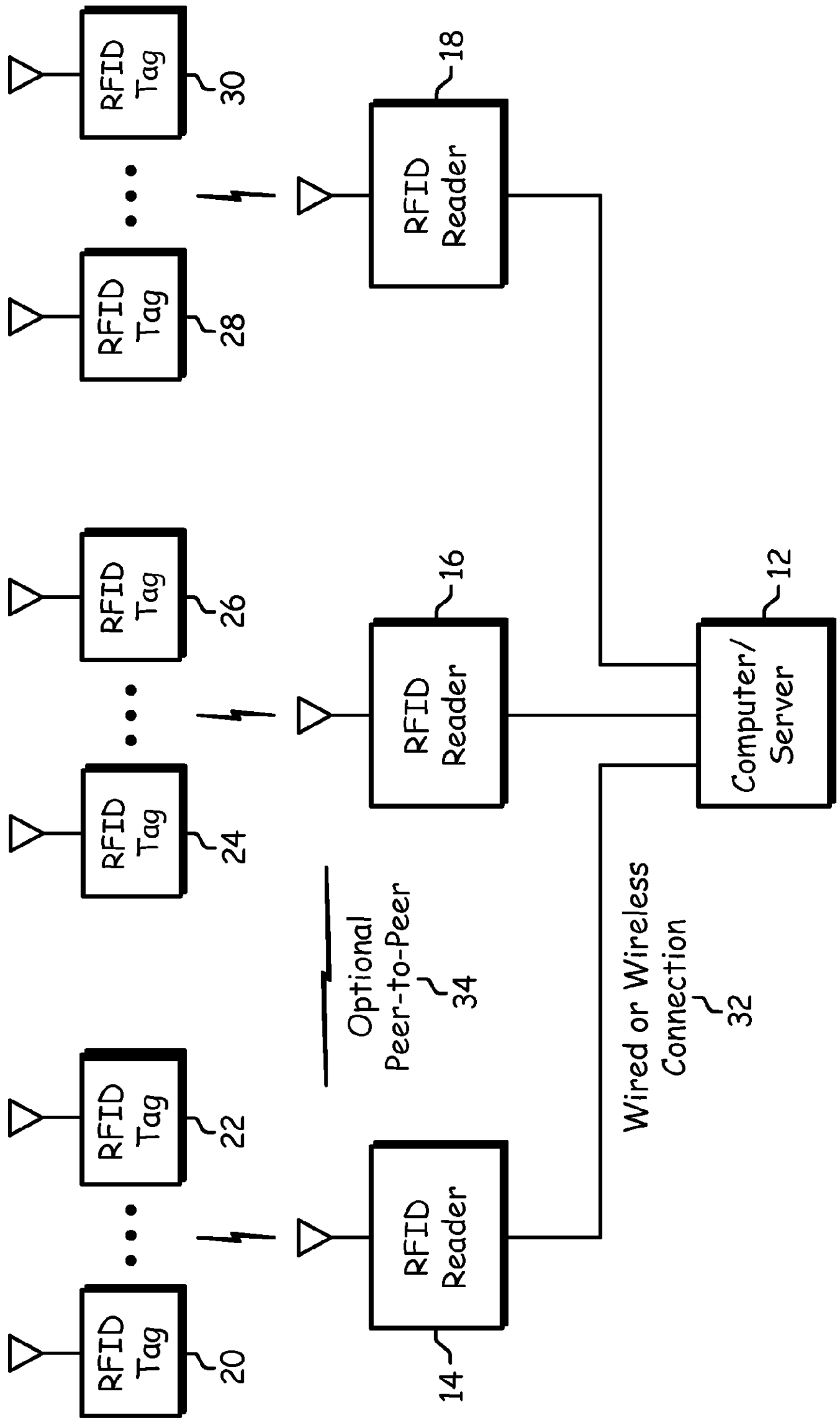

RFID Tag
30
RFID Tag
28
RFID Reader
18
RFID Tag
26
RFID Tag
24
RFID Reader
16
Computer/ Server
12
RFID Tag
22
RFID Tag
20
RFID Reader
14
Optional Peer-to-Peer
34
Wired or Wireless Connection
32

FIG. 1

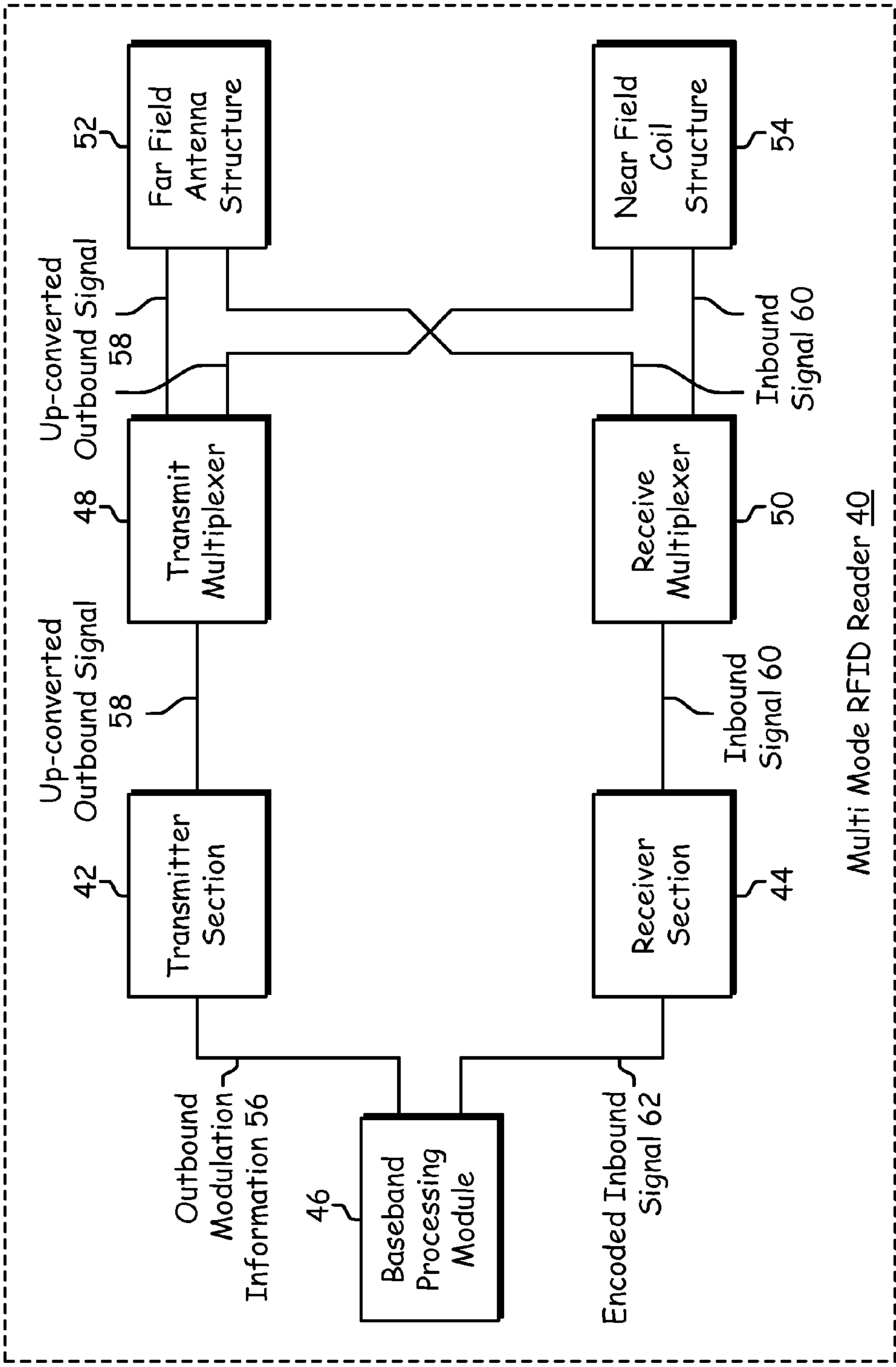

Far Field Antenna Structure
52
Near Field Coil Structure
54
Up-converted Outbound Signal 58
Inbound Signal 60
Transmit Multiplexer
48
Receive Multiplexer
50
Up-converted Outbound Signal 58
Inbound Signal 60
Transmitter Section
42
Receiver Section
44
Outbound Modulation Information 56
Baseband Processing Module
46
Encoded Inbound Signal 62
Multi Mode RFID Reader 40

FIG. 2

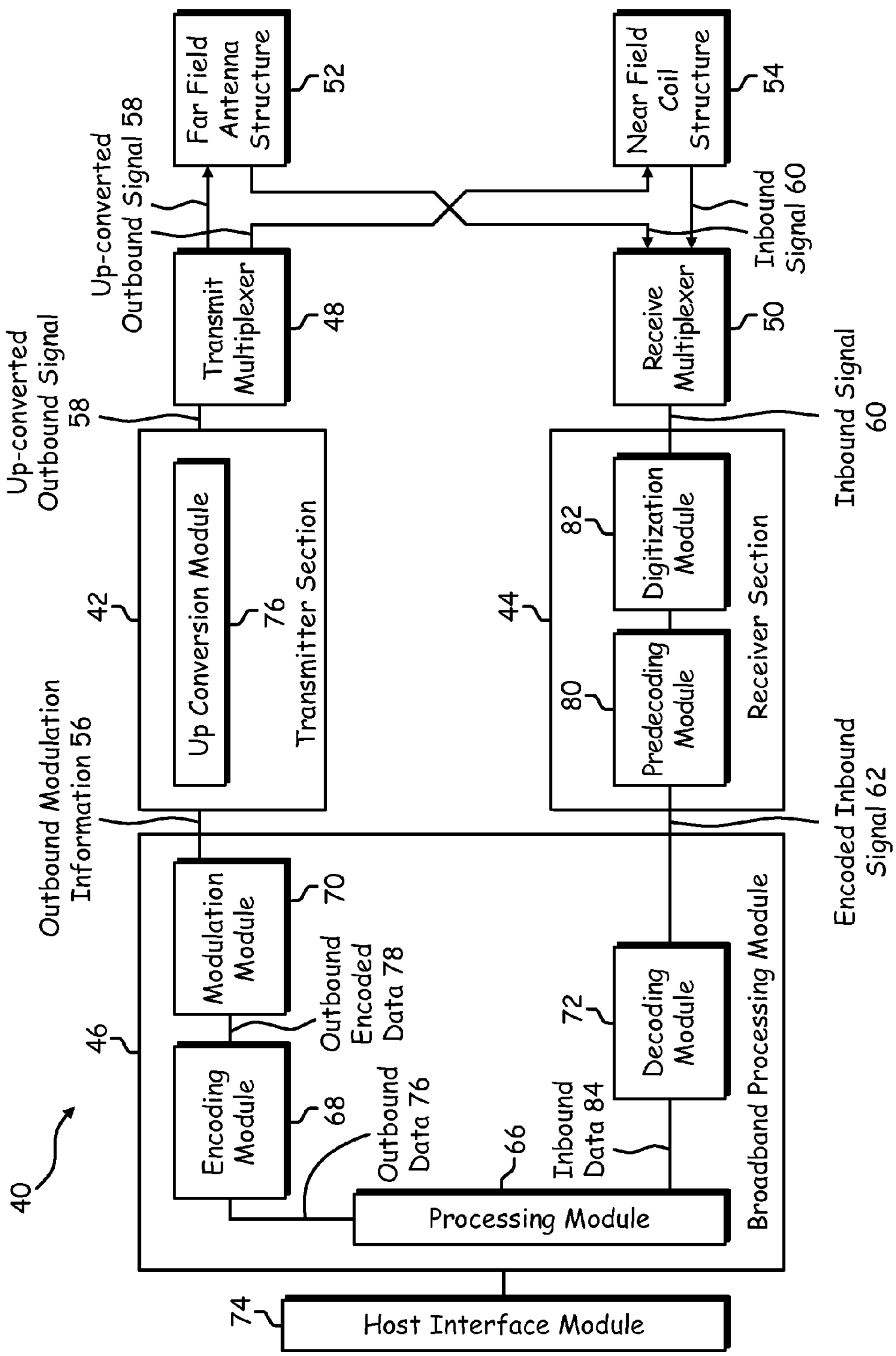

40
Host Interface Module
74
Processing Module
66
Broadband Processing Module
46
Encoding Module
68
Outbound Data 76
Modulation Module
70
Outbound Encoded Data 78
Decoding Module
72
Inbound Data 84
Outbound Modulation Information 56
Encoded Inbound Signal 62
Up Conversion Module
76
Transmitter Section
42
Predecoding Module
80
Digitization Module
82
Receiver Section
44
Up-converted Outbound Signal 58
Inbound Signal 60
Transmit Multiplexer
48
Receive Multiplexer
50
Up-converted Outbound Signal 58
Inbound Signal 60
Far Field Antenna Structure
52
Near Field Coil Structure
54

FIG. 3

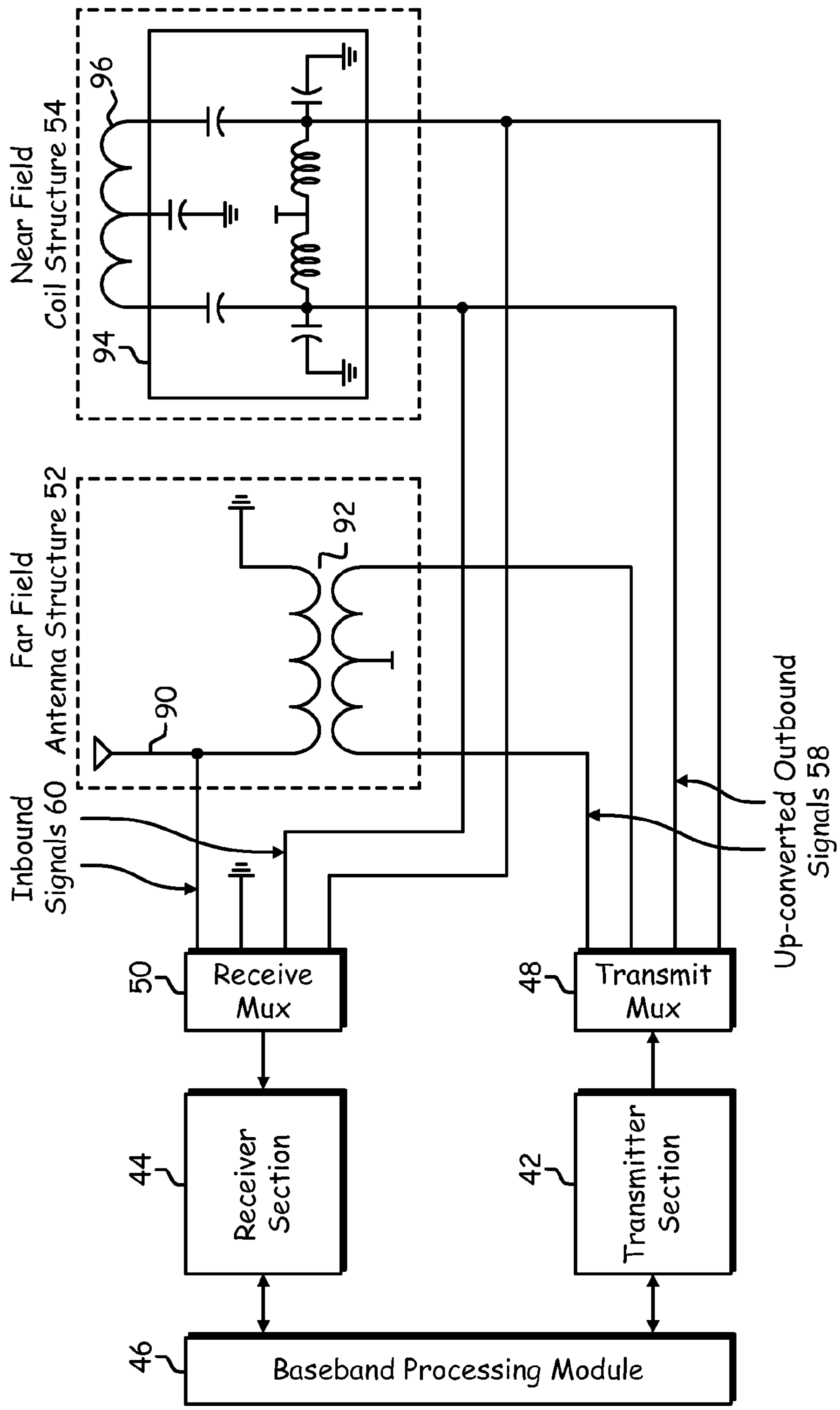

Near Field
Coil Structure 54
96
94
Far Field
Antenna Structure 52
92
90
Inbound
Signals 60
Up-converted Outbound
Signals 58
50
Receive
Mux
48
Transmit
Mux
44
Receiver
Section
42
Transmitter
Section
46
Baseband Processing Module

FIG. 4a

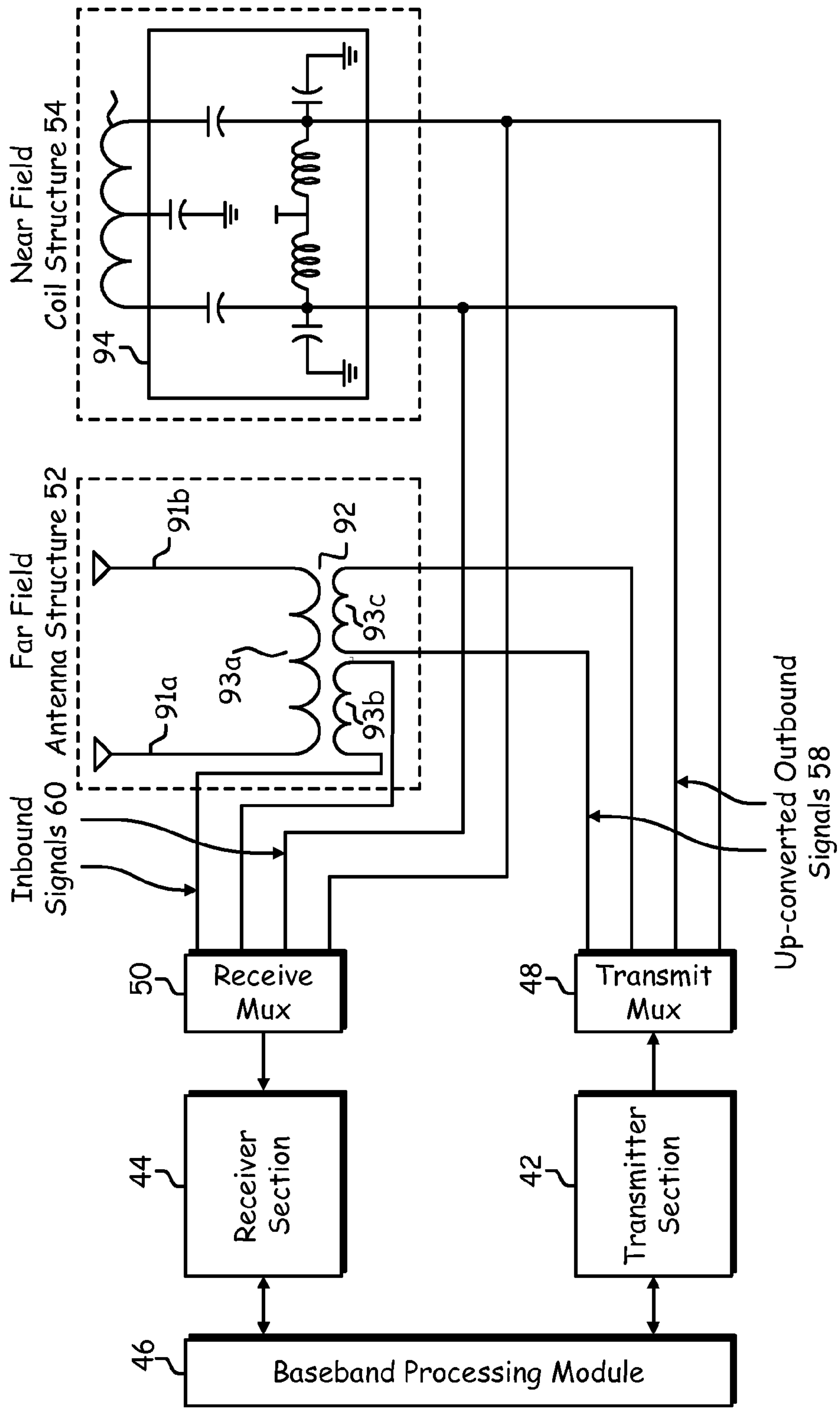

Near Field
Coil Structure 54
94
Far Field
Antenna Structure 52
91b
92
91a
93a
93c
93b
Inbound
Signals 60
Up-converted Outbound
Signals 58
50
Receive
Mux
48
Transmit
Mux
44
Receiver
Section
42
Transmitter
Section
46
Baseband Processing Module

FIG. 4b

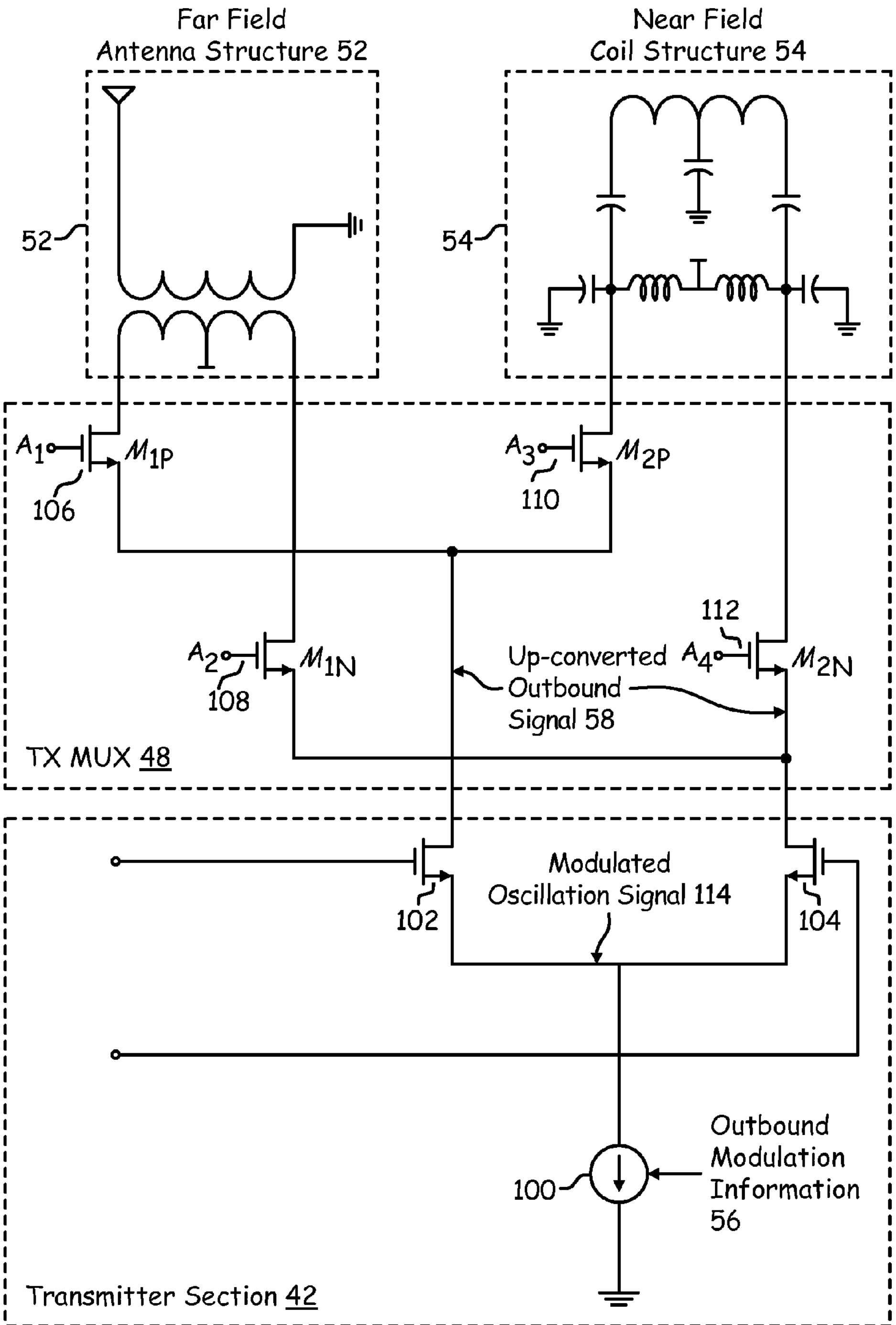
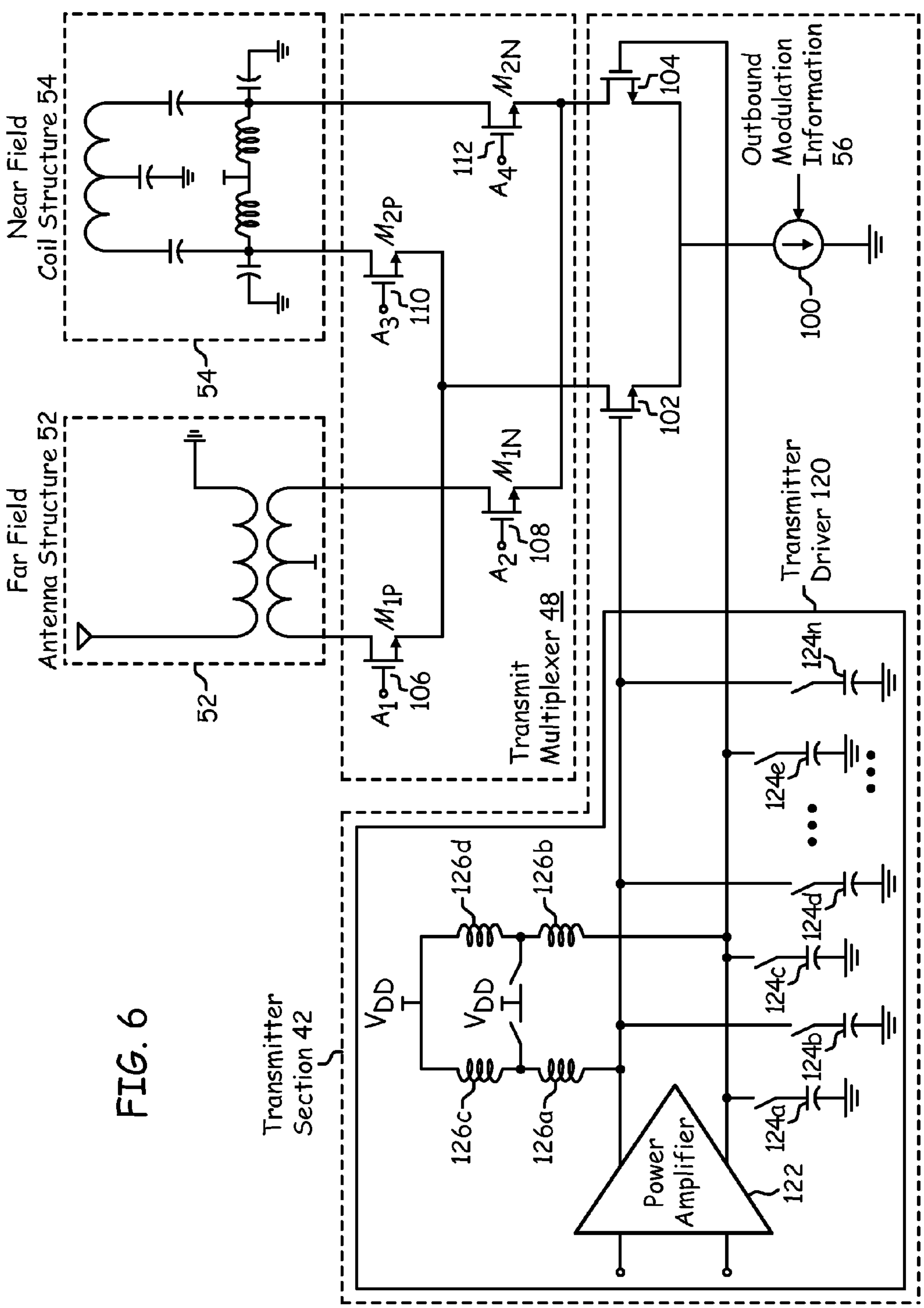

Far Field
Antenna Structure 52
Near Field
Coil Structure 54
52
54
A1
M1P
106
A3
M2P
110
112
A2
M1N
108
Up-converted
Outbound
Signal 58
A4
M2N
TX MUX 48
Modulated
Oscillation Signal 114
102
104
Outbound
Modulation
Information
56
100
Transmitter Section 42

FIG. 5



Far Field Antenna Structure 52
52
Near Field Coil Structure 54
54
Transmit Multiplexer 48
A1
106
M1P
A2
108
M1N
A3
110
M2P
A4
112
M2N
102
104
Outbound Modulation Information 56
100
Transmitter Driver 120
Transmitter Section 42
VDD
VDD
126a
126b
126c
126d
124a
124b
124c
124d
124e
124n
Power Amplifier
122

FIG. 6

MULTI-MODE RFID READER ARCHITECTURE

CROSS REFERENCE TO RELATED PATENTS

[0001] This U.S. patent application claims priority under 35 USC § 119 to a provisionally filed patent application entitled, "RFID System," having a provisional filing date of Mar. 30, 2007, and a provisional application Ser. No. 60/921,221. This U.S. patent application claims priority under 35 USC § 119 to a provisionally filed patent application entitled, "RFID System," having a provisional filing date of May 31, 2007, and a provisional Ser. No. 60/932,411.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

[0003] Not applicable.

BACKGROUND OF THE INVENTION

[0004] 1. Technical Field of the Invention

[0005] This invention relates generally to communication systems and more particularly to RFID systems.

[0006] 2. Description of Related Art

[0007] A radio frequency identification (RFID) system generally includes a reader, also known as an interrogator, and a remote tag, also known as a transponder. Each tag stores identification or other data for use in identifying a person, item, pallet or other object or data related to a characteristic of a person, item, pallet or other object. RFID systems may use active tags that include an internal power source, such as a battery, and/or passive tags that do not contain an internal power source, but instead are remotely powered by the reader.

[0008] Communication between the reader and the remote tag is enabled by radio frequency (RF) signals. In general, to access the identification data stored on an RFID tag, the RFID reader generates a modulated RF interrogation signal designed to evoke a modulated RF response from a tag. The RF response from the tag includes the coded data stored in the RFID tag. The RFID reader decodes the coded data to identify or determine the characteristics of a person, item, pallet or other object associated with the RFID tag. For passive tags, the RFID reader also generates an unmodulated, continuous wave (CW) signal to activate and power the tag during data transfer.

[0009] RFID systems typically employ either far field or near field technology. In far field technology, the distance between the RFID reader and the tag is great compared to the wavelength of the carrier signal. Typically, far field technology uses carrier signals in the ultra high frequency or microwave frequency ranges. In far-field applications, the RFID reader generates and transmits an RF signal via an antenna to all tags within range of the antenna. One or more of the tags that receive the RF signal responds to the reader using a backscattering technique in which the tags modulate and reflect the received RF signal.

[0010] In near-field technology, the operating distance is usually less than one wavelength of the carrier signal. Thus, the reading range is approximately limited to 20 cm or less depending on the frequency. In near field applications, the RFID reader and tag communicate via electromagnetic or inductive coupling between corresponding reader and tag coil antennas. Typically, the near field technology uses carrier signals in the low frequency range.

[0011] The International Organization for Standardization (ISO) has developed an RFID standard called the ISO 18000 series. The ISO 18000 series standard describes air interface protocols for RFID systems especially in applications used to track items in a supply chain. The ISO 18000 series has seven parts to cover the major frequencies used in RFID systems around the world. The seven parts are:

[0012] 18000-1: Generic parameters for air interfaces for globally accepted frequencies;

[0013] 18000-2: Air interface for below 135 KHz;

[0014] 18000-3: Air interface for 13.56 MHz;

[0015] 18000-4: Air interface for 2.45 GHz;

[0016] 18000-5: Air interface for 5.8 GHz;

[0017] 18000-6: Air interface for 860 MHz to 930 MHz;

[0018] 18000-7: Air interface at 433.92 MHz.

[0019] According to the ISO 18000-2 and 18000-3 parts of the ISO 18000 series, near-field technology with magnetic/inductive coupling has an air interface protocol at low frequency (LF) of 135 KHz or less or at 13.56 MHz high frequency (HF). The communication protocol used by the reader and the tag is typically a load modulation technique.

[0020] Far field technology with RF coupling has three ISO defined air interfaces at 2.45 GHz microwave frequency according to ISO 18000-5, 860 MHZ to 930 MHz ultra high frequency (UHF) range according to ISO 18000-6 and 433.92 MHz UHF according to ISO 18000-7. For UHF at 860-930 MHz, the ISO 18000-6 has defined two tag types, Type A and Type B with a reader to tag link defined as including either 33 kbps or 40 kbps data rate, Amplitude Shift Keying (ASK) modulation, and biphase-space (FM**0**) encoding of data.

[0021] In addition, the EPCglobal Class 1, Generation 2 standard defines a tag standard using UHF with a tag to reader link of 40 to 640 kbps, ASK or Phase Shift Keying (PSK) modulation and data encoding of biphase space (FM**0**) or Miller-modulated subcarrier.

[0022] Generally, RFID readers employing near field technology operating at LF or HF have been used in applications involving reading item-level tagging for inventory control in the supply chain management or applications involving short range reads such as smart cards or vicinity credit cards, e.g. for access control or monetary use, passports, money bills authentication, bank documents, etc. Such applications do not need long range reads of the tags but may need more security provided by near field technology. In addition, near field technology is known for better performance for reading of tags near fluids, such as fluid medications, wherein far field RF coupling tends to incur interference from the fluids.

[0023] RFID readers employing far field technology RF coupling at microwave or UHF have been used to read tags in applications involving shipping units such as pallets or carton level tracking or other applications needing long-distance reads.

[0024] Currently, an RFID reader may consist of a controller or microprocessor implemented on a CMOS integrated circuit and a radio implemented on one or more separate CMOS, BiCMOS or GaAs integrated circuits that are uniquely designed for optimal signal processing in a particular technology (e.g., near-field or far-field), but not in both. These different types of technology and the number of different RFID standards, each defining a different protocol for enabling communication between the reader and the tag, has inhibited the wide spread use of RFID readers for multiple applications. Therefore, a need exists for a highly integrated, low-cost RFID reader. In addition, a need exists for a multi-standard, multi-technology RFID reader.

BRIEF SUMMARY OF THE INVENTION

[0025] The present invention is directed to apparatus and methods of operation that are further described in the following Brief Description of the Drawings, the Detailed Description of the Invention, and the claims. Other features and advantages of the present invention will become apparent from the following detailed description of the invention made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0026] FIG. **1** is a schematic block diagram of an embodiment of an RFID system in accordance with the present invention;

[0027] FIG. **2** is a schematic block diagram of an embodiment of a multi-mode RFID reader in accordance with the present invention;

[0028] FIG. **3** is a schematic block diagram of another embodiment of a multi-mode RFID reader in accordance with the present invention;

[0029] FIG. **4***a* is a schematic block diagram of one embodiment of the near field coil structure and the far field antenna structure of a multi-mode RFID reader in accordance with the present invention;

[0030] FIG. **4***b* is a schematic block diagram of another embodiment of the near field coil structure and the far field antenna structure of a multi-mode RFID reader in accordance with the present invention;

[0031] FIG. **5** is a schematic block diagram of one embodiment of a transmit multiplexer and transmitter section of a multi-mode RFID reader in accordance with the present invention; and

[0032] FIG. **6** is a schematic block diagram of one embodiment of a transmitter driver circuit module in a transmitter section of a multi-mode RFID reader in accordance with the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0033] FIG. **1** is a schematic block diagram of an RFID (radio frequency identification) system that includes a computer/server **12**, a plurality of RFID readers **14-18** and a plurality of RFID tags **20-30**. The RFID tags **20-30** may each be associated with a particular object for a variety of purposes including, but not limited to, tracking inventory, tracking status, location determination, assembly progress, et cetera. The RFID tags may be active devices that include internal power sources or passive devices that derive power from the RFID readers **14-18**.

[0034] Each RFID reader **14-18** wirelessly communicates with one or more RFID tags **20-30** within its coverage area. For example, RFID tags **20** and **22** may be within the coverage area of RFID reader **14**, RFID tags **24** and **26** may be within the coverage area of RFID reader **16**, and RFID tags **28** and **30** may be within the coverage area of RFID reader **18**. In far field mode of operation, the RF communication scheme between the RFID readers **14-18** and RFID tags **20-30** is a backscatter coupling technique using far field technology whereby the RFID readers **14-18** request data from the RFID tags **20-30** via an RF signal, and the RF tags **20-30** respond with the requested data by modulating and backscattering the RF signal provided by the RFID readers **14-18**. In a near field mode of operation, the RF communication scheme between the RFID readers **14-18** and RFID tags **20-30** is a magnetic or inductive coupling technique whereby the RFID readers **14-18** magnetically or inductively couple to the RFID tags **20-30** to access the data on the RFID tags **20-30**. Thus, in one embodiment of the current invention, the RFID readers **14-18** may communicate in a far field mode to an RFID tag **20-30** with far field mode capabilities and in a near field mode to an RFID tag **20-30** with near field mode capabilities.

[0035] The RFID readers **14-18** collect data as may be requested from the computer/server **12** from each of the RFID tags **20-30** within its coverage area. The collected data is then conveyed to computer/server **12** via the wired or wireless connection **32** and/or via peer-to-peer communication **34**. In addition, and/or in the alternative, the computer/server **12** may provide data to one or more of the RFID tags **20-30** via the associated RFID reader **14-18**. Such downloaded information is application dependent and may vary greatly. Upon receiving the downloaded data, the RFID tag **20-30** can store the data in a non-volatile memory therein.

[0036] As indicated above, the RFID readers **14-18** may optionally communicate on a peer-to-peer basis such that each RFID reader does not need a separate wired or wireless connection **32** to the computer/server **12**. For example, RFID reader **14** and RFID reader **16** may communicate on a peer-to-peer basis utilizing a back scatter technique, a wireless LAN technique, and/or any other wireless communication technique. In this instance, RFID reader **16** may not include a wired or wireless connection **32** to computer/server **12**. In embodiments in which communications between RFID reader **16** and computer/server **12** are conveyed through the wired or wireless connection **32**, the wired or wireless connection **32** may utilize any one of a plurality of wired standards (e.g., Ethernet, fire wire, et cetera) and/or wireless communication standards (e.g., IEEE 802.11x, Bluetooth, et cetera).

[0037] In other embodiments, the RFID system of FIG. **1** may be expanded to include a multitude of RFID readers **14-18** distributed throughout a desired location (for example, a building, office site, et cetera) where the RFID tags **20-30** may be associated with access cards, smart cards, mobile phones, personal digital assistants, laptops, personal computers, inventory items, pallets, cartons, equipment, personnel, et cetera. In addition, it should be noted that the computer/server **12** may be coupled to another server and/or network connection to provide wide area network coverage.

[0038] FIG. **2** is a schematic block diagram of an embodiment of a multi-mode RFID reader **40** which can be used as one of the RFID readers **14-18** in FIG. **1**. The multi-mode RFID reader **40** is operable to communicate in a far field mode to an RFID tag **20-30** with far field capability and/or in a near field mode to an RFID tag **20-30** with near field capability. The multi-mode RFID reader **40** includes a transmitter section **42**, a receiver section **44** and baseband processing module **46**. The multi-mode RFID reader **40** also includes a transmit multiplexer **48** and a receive multiplexer **50**. Both the transmit multiplexer **48** and the receive multiplexer **50** are coupled to a far field antenna structure **52** and a near field coil structure **54**.

[0039] The baseband processing module **46**, transmitter section **42** and receiver section **44** may be a single processing device or a plurality of processing devices. Such a processing device may be a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on hard coding of the circuitry and/or operational instructions. One or more of the modules may have an associated memory element, which may be a single memory device, a plurality of memory devices, and/or embedded circuitry of the module. Such a memory device may be a read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when the module implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory element storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry. Further note that, the memory element stores, and the module executes, hard coded and/or operational instructions corresponding to at least some of the steps and/or functions illustrated in FIGS. **1-6**.

[0040] In operation, the baseband processing module **46** converts outbound data into outbound modulation information **5** and transmits the outbound modulation information **56** to transmitter section **42**. The transmitter section **42** is operable to convert the outbound modulation information **56** into an up-converted outbound signal **58**. The up-converted outbound signal **58** has a carrier frequency within the RF band and/or in the microwave band. In one embodiment, the up-converted outbound signal **58** is in the UHF range, and in particular in one embodiment, the up-converted outbound signal **58** is in the 860 MHz to 930 MHz UHF range. The transmitter section **42** is coupled to the transmit multiplexer **48**. The transmit multiplexer **48** receives the up-converted outbound signal **58** from the transmitter section **42** and is operable to couple the up-converted outbound signal **58** to the near field coil structure **54** when the RFID reader **40** is in a near field mode and to output the up-converted outbound signal **58** to the far field antenna structure **52** when the RFID reader **40** is in a far field mode.

[0041] To receive signals, an inbound UHF signal **60** is detected at either the far field antenna structure **52** or the near field coil structure **54**. The receive multiplexer **50** is coupled to output the inbound signal **60** from the near field coil structure **54** to the receiver section **44** when the RFID reader **40** is in the near field mode and to output the inbound signal **60** from the far field antenna structure **52** to the receiver section **50** when the RFID reader **40** is in the far field mode. The inbound signal **60** has a carrier frequency within the RF band and/or in the microwave band. In one embodiment, the inbound signal **60** is in the UHF range, and in particular in one embodiment, the inbound signal **60** is in the 860 MHz to 930 MHz UHF range. The receiver section **44** is operable to down convert the inbound signal **60** into an encoded inbound signal **62**. The baseband processing module **46** is operable to convert the encoded inbound signal **62** into inbound data.

[0042] FIG. **3** illustrates one embodiment of the multi-mode RFID reader **40** in more detail. As seen in FIG. **3**, the baseband processing module **46** includes a processing module **66**, an encoding module **68**, modulation module **70** and decoding module **72**. The baseband processing module **46** is also coupled to a host interface **74**. The host interface module **74** may include a communication interface (USB dongle, compact flash or PCMCIA) to a host device, such as the computer server **12**. In addition, the multi-mode RFID reader **40** includes an up conversion module **76** as part of the transmitter section **42** and a predecoding module **80** and digitization module **82** as part of the receiver section **44**. The digitization module **82** may be an analog to digital convertor or a limiter while the predecoding module **80** includes one or more digital filters.

[0043] In operation, the processing module **66** may receive one or more commands or requests for data from the host interface module **74** that requires communication of data to one or more RFID tags **20-30**. Alternatively, or in addition to, the processing module **66** may receive data from an RFID tag **20-30** that requires a response to be generated by the multi-mode RFID reader **40**. As another alternative, or in addition to, the processing module **66** may determine itself that a command or other communication is necessary to one or more RFID tags **20-30**. In response to the required communication, the processing module **66** generates outbound data **76** for communication to one or more RFID tags **20-30** and transmits the outbound data **76** to the encoding module **68**.

[0044] The encoding module **68** is operable to convert the outbound data **76** into outbound encoded data **78** in accordance with a particular RFID standardized protocol. In an embodiment, the baseband processing module **46** is programmed with multiple RFID standardized and/or proprietary encoding protocols to enable the multi-mode RFID reader **40** to communicate with RFID tags **20-30** operating in accordance with different standardized and/or proprietary encoding protocols. By way of example, but not limitation, the encoding protocols may include one or more encoding schemes, such as Manchester encoding, FM**0** encoding, FM**1** encoding, etc. In particular, the encoding protocol utilized may depend on the mode of operation of the RFID reader **40**. Different encoding protocols may be defined for encoding data for transmission in near field mode and in far field mode. For example, in near field mode, a first data encoding protocol may be used by the baseband processing module **46** for encoding data while a second data encoding protocol may be used by the baseband processing module **46** for encoding data in far field mode. A typical encoding protocol in near field mode includes Manchester coding, although other encoding protocols may be used. Also, in far field mode, typical encoding protocols comprise at least one of the following: Miller-modulated subcarrier coding and biphase-space encoding although other encoding protocols may be used. In addition, the first data encoding protocol for encoding outbound data **76** in near field mode may the same as the second data encoding protocol for encoding outbound data **76** in far field mode.

[0045] Once the particular encoding protocol has been selected for communication with one or more RFID tags **20-30**, the processing module **66** generates and provides the outbound data **76** to be communicated to the RFID tag **20-30** to the encoding module **78**. The processing module **66** communicates the encoding protocol selected, and the encoding module **78** encodes the outbound data **76** in accordance with the selected encoding protocol to convert the outbound data **76** into the outbound encoded data **78**.

[0046] Thereafter, the outbound encoded data **78** is provided to the modulation module **70** which converts the outbound encoded data **78** into outbound modulation information **56**(e.g., phase, frequency, and/or amplitude modulation information). In an embodiment, the outbound modulation information **56** is one or more of binary phase shift keying (BPSK), quadrature PSK (QPSK), quadrature amplitude modulation (QAM), amplitude shift keying (ASK) modulation information, phase shift keying (PSK), load modulation, frequency shift keying (FSK), minimum shift keying (MSK), etc.

[0047] The outbound modulation information **56** is transmitted to the up conversion module **76**, which utilizes the outbound modulation information **56** to generate an up-converted signal **58** at a carrier frequency in the RF band or microwave band. In one embodiment, the carrier frequency is in the ultra high frequency (UHF) range, which is approximately 300 MHz to 3 GHz. In an embodiment, the particular carrier frequency used by the multi-mode RFID reader **40** is a standardized carrier frequency in the UHF range, such as the ISO 18000 series 860-930 MHz UHF range or according to EPCglobal standards or other standards. However, the multi-mode RFID reader may be optimized for operation for any frequency within the RF band or microwave band, and in one embodiment in the UHF range.

[0048] The transmit multiplexer **48** is operable to have the up-converted outbound signal **58** transmitted by the near field coil structure **54** when the RFID reader **40** is in a near field mode and to have the up-converted outbound signal **58** transmitted by the far field antenna structure **52** when the RFID reader **40** is in a far field mode. In one embodiment, the RFID reader **40** generates an up-converted outbound signal **58** in the UHF range in both near field and far field mode, e.g. in the ISO 18000 series 860-930 MHz UHF range. In such an embodiment, the up-converted outbound signal **58** is in the UHF range even when transmitting over the near field coil structure **54** in near field mode using inductive or magnetic coupling.

[0049] In operation to receive an inbound signal **60**, the receive multiplexer **50** is coupled to output the inbound signal **60** from the near field coil structure **54** to the receiver section **44** when the RFID reader **40** is in the near field mode and to output the inbound signal **60** from the far field antenna structure **52** to the receiver section **44** when the RFID reader **40** is in the far field mode. In one embodiment, the inbound signal **60** is in the UHF range in both near field and far field mode, e.g. in the ISO 18000 series 860-930 MHz UHF range. In such an embodiment, the inbound signal **60** is in the UHF range even when receiving the inbound signal **60** over the near field coil structure **54** in near field mode using inductive or magnetic coupling.

[0050] The digitization module **82** and predecoding module **80** in the receiver section **44** converts the analog inbound signal **60** into digital encoded inbound signal **62**. The receiver section **44** is operable to transmit the encoded inbound signal **62** to the baseband processing module **46**. The decoding module **72** in the baseband processing module **46** decodes the encoded inbound signal **62**. As explained above in an embodiment, the baseband processing module **46** is programmed with multiple RFID standardized protocols such that the decoding module **72** is operable to decode the encoded inbound signal **62** using one or more encoding protocols. By way of example, but not limitation, the encoding protocols may include one or more encoding schemes, such as Manchester encoding, FM**0** encoding, FM**1** encoding, etc. In particular, the encoding scheme utilized may depend on the mode of operation of the RFID reader **40**. Different data encoding protocols may be defined for decoding data in near field mode and in far field mode. When operating in near field mode, the decoding module **72** may attempt to decode the encoded inbound signal **62** using a first protocol typical in near field operations, such as Manchester coding. If such decoding is unsuccessful, the decoding module **72** is operable to attempt to decode the encoded inbound signal **62** with a next protocol until the encoded inbound signal **62** is decoded. Similarly, when operating in far field mode, the decoding module **72** may attempt to decode the encoded inbound signal **62** using a second protocol typical in far field operations, such as Miller-modulated subcarrier coding and biphase-space encoding. If such decoding is unsuccessful, the decoding module **72** is operable to attempt decoding the encoded inbound signal **62** with a next protocol until the encoded inbound signal **62** is decoded. Once the particular encoding protocol has been determined for decoding the encoded inbound signal **62**, the decoding module **72** decodes and generates the inbound data **84** to be communicated to the processing module **66**.

[0051] The processing module **66** signals the other modules of the RFID reader **40**, such as the encoding module **66**, modulation module **70**, transmitter section **42** and/or transmit multiplexer **48**, the receiver section **44** and/or receive multiplexer **50** that the RFID reader **40** is operating in the near field mode or the far field mode. Various factors may determine whether the RFID reader **40** operates in near field mode or far field mode. For example, the RFID reader **40** may default to far field mode or a user input to the RFID reader **40** may determine the mode of operation or a command received through the hose interface module **74** may determine the mode of operation. In another alternative, the RFID reader **40** may transmit an interrogation signal to one or more tags **20-30** in far field mode using RF coupling over the far field antenna structure **52**, and then transmit an interrogation signal to one or more tags **20-30** in near field mode using inductive or magnetic coupling over the near field antenna structure. The RFID reader **40** may then compare an input signal strength indication, transmit power levels, signal to noise ratio, ability to decode the inbound signal (e.g., error rate), and/or other indicators to determine the mode of operation to communicate with each tag **20-30**.

[0052] In addition, certain tags **20-30** (hereinafter called multi-mode tags) may be operable to communicate in both near field mode and far field mode. See, e.g., U.S. Patent Application No. ______, filed ______, entitled, "Multi-Mode RFID Tag Architecture," by ______, Attorney Docket No. BP6584, the entirety of which is incorporated herein. It may be advantageous to communicate in both modes with such a multi-mode tag. For example, when such a multi-mode tag is farther away, such as in a far field range, the RFID reader **40** operates in far field mode to communicate with the multi-mode tag. When the tag is in a closer near field range, the RFID reader operates in a near field mode to communicate with the multi-mode tag. In another method of operation, the RFID reader may operate in far field mode for general interrogation signals to multi-mode RFID tags but then operate in near field mode for more secure communications involving confidential, sensitive or private information to a particular multi-mode tag. To switch from one mode of operation to another during a communication with a multi-mode tag, the baseband processing module **46** encodes a data signal command for transmission in far field mode to one or more multi-mode tags to operate in near field mode; and upon receipt of a decoded inbound data **84** from the one or more multi-mode tags with an acknowledgement of the command, the baseband processing module **46** signals the other modules in the RFID reader **46** to operate in near field mode to communicate with the one or more multi-mode tags. The same procedure may be used to switch from near field mode to far field mode.

[0053] FIG. **4***a* illustrates one embodiment of the near field coil structure **54** and the far field antenna structure **52** in more detail. First, with respect to the far field antenna structure **52**, generally, RFID reader to tag distances greater than $\lambda/2\pi$ are optimal for far field mode with RF coupling. Thus, the far field antenna structure **52** may be any type of antenna structure for transmitting in the far field range. In one embodiment shown in FIG. **41**, the far field antenna structure **52** includes at least one antenna **90** and at least one transformer balun **92**. The antenna **90** and transformer balun **92** are optimized for transmitting the up-converted outbound signal **58** using RF coupling in far field mode and receiving of the inbound signal **60** using RF coupling in far field mode. The antenna **90** can be one or more of several types of antennas optimized for the desired frequency of operation and application. The antenna **90** may be a dipole type antenna, a folded dipole, a half-wave dipole, monopole, differential antenna and/or another type antenna. In one embodiment, the antenna **90** can be bent or meandered with capacitive tip-loading or bowtie-like broadband structures. The transformer balun **92** provides impedance matching for the antenna **90**. Other types of transformers or impedance circuits may be used with or in place of the transformer balun **92** to provide the necessary impedance matching needed for the antenna **90**. In FIG. **4***a*, the receive multiplexer **50** is connected to the single ended antenna **90**. However, the antenna **90** may be a differential antenna and/or the receive multiplexer **50** may also be connected to the output of the transformer balun **92** as with the transmit multiplexer **48**.

[0054] Another embodiment of the far field antenna structure is shown in FIG. **4***b*. The far field antenna structure **52** includes a first antenna **91***a* and a second antenna **91***b*. The antennas **91***a* and **91***b* are differential antennas. The far field antenna structure also includes a transformer balun **92** with a primary winding **93***a* connected to the first antenna **91***a* and second antenna **91***b*. The secondary winding **93***b,c* has a four differential input wherein the secondary winding **93***b* has more turns between the inputs connected to the receive multiplexer **44**. The secondary winding **93***c* connected to the transmit multiplexer has a smaller number of turns. Since the ratio of the primary winding turns to the secondary winding turns of a transformer is proportional to the voltage gain, the receive input thus has a larger voltage gain. In far field mode, the up-converted outbound signals **58** are transmitted from the far field antenna structure **52** by RF coupling to an RF antenna structure on a tag **20-30**, and the inbound signals **60** are received by the far field antenna structure **52** by RF coupling to an RF antenna structure on a tag **20-30**.

[0055] The near field coil structure **54** includes at least one inductor that operates as a coil antenna **96** and at least one impedance coupling circuit **94**. The impedance coupling circuit **94** includes one or more capacitors C**1**-C**3** coupled with one or more inductors L**1**, L**2**. The inductors L**1**, L**2** and the capacitors C**1**-C**3** form a resonant circuit with the coil antenna **96** tuned to the frequency of the up-converted outbound signal **58**. Due to the parallel resonant circuit, the up-converted outbound signal **58** through the coil antenna **96** generates a strong magnetic field around the coil antenna **96**. The magnetic field generated by the coil antenna **96** produces an inductive or magnetic coupling with a coil antenna of a tag **20-30** within the near field of the coil antenna **96**. If the coil antenna **96** is a round or u-shaped ferrite core with windings, a magnetic coupling with a tag occurs in near field mode. Generally, with magnetic coupling, the tag **20-30** must be inserted into the RFID reader **40** so magnetic coupling is ideal for smart card applications. Generally, RFID reader to tag distances less than $\lambda/2\pi$ are optimal for near field mode with inductive or magnetic coupling. The tag generates and transmits a response signal to the RFID reader through inductive or magnetic coupling in the same manner.

[0056] The RFID reader **40** operates in either far field mode or near field mode. In far field mode, the transmit multiplexer **48** provides the up-converted outbound signal or signals **58** to the far field antenna structure **52** and the receive multiplexer **50** provides inbound UHF signal or signals **60** to the receiver section **44**. In far field mode, the near field coil structure **54** is inactive. For near field operation, the transmit multiplexer **48** provides the up-converted outbound signal or signals **58**, to the near field coil structure **54** and the receive multiplexer **50** provides inbound signal or signals **60** to the receiver section **44**. In near field mode, the far field antenna structure **52** is inactive.

[0057] FIG. **5** illustrates one embodiment of the transmit multiplexer and transmitter section of the RFID reader **40** in more detail. The transmitter section **42** includes a current source **100** and input transistors **102**, **104**. The transmit multiplexer **48** includes multiplexer transistors **106**, **108**, **110**, **112**. The multiplexer transistors **106**, **108** are coupled to the input transistors **102**, **104** and to the RFID far field antenna structure **52**. The multiplexer transistors **110**, **112** are coupled to the input transistors **102**, **104** and the RFID near field antenna structure **54**. Each of the multiplexer transistors **106**, **108**, **110** and **112** include an activation input (e.g., a gate) A_1 through A_4, respectively.

[0058] In operation, the current source **100** is modulated based on the outbound modulation information **56** from the baseband processing module **46**. In an embodiment, the current source **100** is in the ultra high frequency range. The input transistors **102**, **104** are coupled to the current source **100** to receive the modulated oscillation signal **114**. In combination, the current source **100** and the input transistors **102**, **104** produce the up-converted outbound signal **58**.

[0059] In far field mode, the transmitter section **42** is operable to transmit a signal to activate the activation input A**1** of multiplexer transistor **106** and activation input A**2** of multiplexer transistor **108**. The multiplexer transistors **106**, **108** are then operable to output the up-converted outbound signal **58** to the far field coil structure **52**. In near field mode, the transmitter section **42** is operable to transmit a signal to activate the activation input A**3** of multiplexer transistor **110** and activation input A**4** of multiplexer transistor **112**. The multiplexer transistors **110**, **112** are then operable to output the up-converted outbound signal **58** to the near field coil structure **54**. Thus, the transmitter section **42** is operable to signal the transmit multiplexer **48** to activate the first set of transistors **106** and **108** to transmit in far field mode and to activate the second set of transistors **110** and **112** to operate in near field mode. Alternatively, the baseband processing module **46** or the processing module **66** may signal the transmit multiplexer **48** rather than the transmitter section **42**.

[0060] FIG. **6** is a schematic block diagram of an embodiment of a transmitter driver circuit module **120** in a transmitter section **42** of the multi mode RFID reader **40**. The transmitter driver circuit module **120** includes a power amplifier **122** with outputs coupled to gates of the input transistors **102**, **104**. A plurality of capacitors **124***a* through **124***n* are configurably coupled to the outputs of the power amplifier and to the gates of the input transistors **102**, **104**. A plurality of inductors **126***a*, **126***b*, **126***c* and **126***d* are configurably coupled to the outputs of the power amplifier **122** and to the gates of the input transistors **102**, **104**.

[0061] In operation, the power amplifier **122** and capacitors **124***a* through **124***n* and inductors **126***a* through **126***d* form a resonant output that can be tuned to the desired frequency of the up-converted outbound signal **58**. The capacitors **124***a* through **124***n* and inductors **126***a* through **126***d* are configurably coupled to the outputs of the power amplifier and to the gates of the input transistors **102**, **104** such that the resonant output may be tuned to the desired frequency. Often capacitors on an integrated circuit or chip have a large tolerance due to process variations and so the configurably coupled capacitors **124***a* through **124***n* can be tuned to overcome this issue.

[0062] The multi-mode RFID reader **40** thus provides near field and far field mode operation. By operating in both near field and far field mode, the RFID reader **40** provides multi-standard, multi-technology option for use in multiple applications. As such, the RFID readers are not limited to only near read or far read applications but can be used in both type applications and are operable to be switched from near field mode to far field mode or from far field mode to near field mode to accommodate different types of RFID tags and differing distances between the multi-mode RFID reader and an RFID tag. In one embodiment, the near field and far field mode operation are both in the UHF range. Though the range of communication is smaller (e.g., <5 mm) in near field mode using UHF signals than at lower frequencies (such as HF and LF), such UHF near field RFID communications are well suited for near read applications, such as inventory items, monitory paper authentication, passports, credit cards, etc. The near field UHF operation of the RFID reader **40** also has more efficient operation near fluids, such as fluid medication bottles.

[0063] As may be used herein, the terms "substantially" and "approximately" provides an industry-accepted tolerance for its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to fifty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. Such relativity between items ranges from a difference of a few percent to magnitude differences. As may also be used herein, the term(s) "coupled to" and/or "coupling" and/or includes direct coupling between items and/or indirect coupling between items via an intervening item (e.g., an item includes, but is not limited to, a component, an element, a circuit, and/or a module) where, for indirect coupling, the intervening item does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As may further be used herein, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two items in the same manner as "coupled to". As may even further be used herein, the term "operable to" indicates that an item includes one or more of power connections, input(s), output(s), etc., to perform one or more its corresponding functions and may further include inferred coupling to one or more other items. As may still further be used herein, the term "associated with", includes direct and/or indirect coupling of separate items and/or one item being embedded within another item. As may be used herein, the term "compares favorably", indicates that a comparison between two or more items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

[0064] While the transistors in the above described figure (s) is/are shown as field effect transistors (FETs), as one of ordinary skill in the art will appreciate, the transistors may be implemented using any type of transistor structure including, but not limited to, bipolar, metal oxide semiconductor field effect transistors (MOSFET), N-well transistors, P-well transistors, enhancement mode, depletion mode, and zero voltage threshold (VT) transistors.

[0065] The present invention has also been described above with the aid of method steps illustrating the performance of specified functions and relationships thereof. The boundaries and sequence of these functional building blocks and method steps have been arbitrarily defined herein for convenience of description. Alternate boundaries and sequences can be defined so long as the specified functions and relationships are appropriately performed. Any such alternate boundaries or sequences are thus within the scope and spirit of the claimed invention.

[0066] The present invention has been described above with the aid of functional building blocks illustrating the performance of certain significant functions. The boundaries of these functional building blocks have been arbitrarily defined for convenience of description. Alternate boundaries could be defined as long as the certain significant functions are appropriately performed. Similarly, flow diagram blocks may also have been arbitrarily defined herein to illustrate certain significant functionality. To the extent used, the flow diagram block boundaries and sequence could have been defined otherwise and still perform the certain significant functionality. Such alternate definitions of both functional building blocks and flow diagram blocks and sequences are thus within the scope and spirit of the claimed invention. One of average skill in the art will also recognize that the functional building blocks, and other illustrative blocks, modules and components herein, can be implemented as illustrated or by discrete components, application specific integrated circuits, processors executing appropriate software and the like or any combination thereof.

1. A multi-mode radio frequency identification (RFID) reader comprises:

a baseband processing module coupled to:

convert outbound data into outbound modulation information; and

convert an encoded inbound signal into inbound data;

a transmitter section coupled to convert the outbound modulation information into an up-converted outbound signal;

a far field antenna structure;

a near field coil structure;

a transmit multiplexer coupled to output the up-converted outbound signal to the near field coil structure when the multi-mode RFID reader is in a near field mode and to output the up-converted outbound signal to the far field antenna structure when the multi-mode RFID reader is in a far field mode;

a receive multiplexer coupled to input an inbound signal from the near field coil structure when the multi-mode RFID reader is in the near field mode and to input the inbound signal from the far field antenna structure when the multi-mode RFID reader is in the far field mode; and

a receiver section coupled to down-convert the inbound signal into the encoded inbound signal.

2. The multi-mode RFID reader of claim **1**, wherein the far field antenna structure comprises:

an antenna;

a transformer balun coupled to the antenna.

3. The multi-mode RFID reader of claim **1**, wherein the near field coil structure comprises:

a plurality of coils;

a plurality of capacitors coupled to the plurality of coils.

4. The multi-mode RFID reader of claim **1**, wherein the transmitter section comprises:

a current source modulated based on the outbound modulation information; and

input transistors coupled to the current source.

5. The multi-mode RFID reader of claim **4**, wherein the transmit multiplexer comprises:

multiplexer transistors operable to couple the input transistors to the near field coil structure when in the near field mode and to the far field antenna structure when in the far field mode.

6. The multi-mode RFID reader of claim **5**, wherein the multiplexer transistors comprise:

a first set of transistors coupled to the input transistors and the near field coil structure, wherein each of the first set of transistors includes an activation input; and

a second set of transistors coupled to the input transistors and the far field antenna structure, wherein each of the second set of transistors includes an activation input.

7. The multi-mode RFID reader of claim **6**, wherein the transmitter section is operable to signal the transmit multiplexer to activate the first set of transistors to transmit in the near field mode and to signal the transmit multiplexer to activate the second set of transistors to transmit in the far field mode.

8. The multi-mode RFID reader of claim **4**, wherein the transmitter section comprises:

a transmitter driver circuit, including:

a power amplifier with outputs coupled to inputs of the input transistors;

a plurality of capacitors configurably coupled to the outputs of the power amplifier and to the inputs of the input transistors; and

a plurality of inductors coupled to the outputs of the power amplifier and to the inputs of the input transistors.

9. The multi-mode RFID reader of claim **1**, wherein the baseband processing module further functions to:

encode the outbound data using a first encoding protocol when in the near field mode and using a second encoding protocol when in the far field mode.

10. The multi-mode RFID reader of claim **1**, wherein the up-converted outbound signal and the inbound signal are in the ultra high frequency (UHF) range.

11. The multi-mode RFID reader of claim **1**, wherein the baseband processing module further functions to transmit one or more control signals to the transmitter section, wherein the transmitter section operates in the far field mode or the near field mode in response to the one or more control signals.

12. The multi-mode RFID reader of claim **11**, wherein the transmitter section further functions to:

signal the transmit multiplexer to couple the up-converted outbound signal to the near field coil structure when the one or more control signals indicates the near field mode; and

signal the transmit multiplexer to couple the up-converted outbound signal to the far field antenna structure when the one or more control signals indicates the far field mode.

13. The multi-mode RFID reader of claim **11**, wherein the baseband processing module further functions to transmit a signal to the transmitter section, wherein the signal indicates whether the transmitter section is to transmit in the far field mode or the near field mode.

14. The multi-mode RFID reader of claim **11**, wherein the baseband processing module is operable to:

in response to a receive signal strength indication from one or more tags, encoding a data signal command for transmission by the transmitter section in the far field mode to the one or more tags to operate in the near field mode; and

upon receipt of a decoded data signal from the one or more tags with an acknowledgement of the command, transmitting the one or more control signals to the transmitter section to transmit in the near field mode to the one or more tags.

15. The multi-mode RFID reader of claim **11**, wherein the baseband processing module is operable to:

in response to a receive signal strength indication from one or more tags or an inbound encoded signal that the baseband processing module is unable to decode, encode a data signal command for transmission by the transmitter section in the near field mode to the one or more tags to operate in the far field mode; and

upon receipt of a decoded data signal from the one or more tags with an acknowledgement of the command, transmitting the one or more control signals to the transmitter section to transmit in the far field mode to the one or more tags.

16. The multi-mode RFID reader of claim **11**, wherein the multi-mode RFID reader operates in the far field mode as a default mode.

17. An radio frequency identification (RFID) reader, comprising:

a baseband processing module operable to:

convert outbound data into outbound encoded data; and

convert the outbound encoded data into outbound modulation information; a transmitter section operable to convert the outbound modulation information into an up-converted outbound signal; and a transmit multiplexer operable to:

couple the up-converted outbound signal to a near field coil antenna structure for inductive coupling to one or more tags in a near field mode; and

couple the up-converted outbound signal to a far field antenna structure for RF radio frequency (RF) coupling to the one or more tags in a far field mode.

18. The RFID reader of claim **17**, further comprising:

a receive multiplexer operable to:

receive an inbound signal from the near field coil antenna structure when the RFID reader is operating in the near field mode;

receive the inbound signal from the far field antenna structure when the reader is operating in the far field mode; and

transmit the received inbound signal to a receiver section.

19. The RFID reader of claim **18**, wherein the receiver section is operable for converting the UHF inbound signal into an encoded inbound signal.

20. The RFID reader of claim **19**, wherein the baseband processing module is operable to:

convert the encoded inbound signal into inbound data using a first encoding protocol when in the near field mode; and

convert the encoded inbound signal into inbound data using a second encoding protocol when in the far field mode.

21. The RFID reader of claim **20**, wherein the baseband processing module is operable to:

convert the outbound data into outbound encoded data using a first encoding protocol when in the near field mode; and

convert the outbound data into outbound encoded data using a second encoding protocol when in the far field mode.

22. The RFID reader of claim **21**, wherein the baseband processing module is operable to:

when the RFID reader is operating in the far field mode, encode a data signal command for transmission in the far field mode to the one or more tags to operate in the near field mode; and

upon receipt of a decoded inbound data from the one or more tags with an acknowledgement of the command, operating the RFID reader in the near field mode.

23. The RFID reader of claim **21**, wherein the baseband processing module is operable to:

when the RFID reader is operating in the near field mode, encode a data signal command for transmission in the near field mode to the one or more tags to operate in the near field mode; and

upon receipt of a decoded inbound data from the one or more tags with an acknowledgement of the command, operating the RFID reader in the far field mode.

24. The RFID reader of claim **17**, wherein the transmit multiplexer comprises:

a first set of transistors coupled to input transistors and the near field antenna coil structure that are operable to couple the up-converted outbound signal to a near field coil antenna structure for inductive coupling to the one or more tags in the near field mode; and

a second set of transistors coupled to the input transistors and the far field antenna structure that are operable to couple the up-converted outbound signal to a far field antenna structure for RF coupling to the one or more tags in the far field mode; and

wherein the transmitter section is operable to signal the transmit multiplexer to activate the first set of transistors to transmit in the near field mode and to signal the transmit multiplexer to activate the second set of transistors to operate in the far field mode.

25. The multi-mode RFID reader of claim **17**, wherein the up-converted outbound signal is in an ultra-high frequency (UHF) range in the near field mode and the far field mode.

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