A Survey of Recent Patents on Radio Frequency Identification Systems and Applications

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Abstract: The generic term radio frequency identification system has become important of late for its huge potential in business applications. These wireless systems usually have two parts, a tag and a reader, that can communicate with each other by using radio frequency energy even at a moderate distance. Since such systems work with non contact as well as non line of sight principle, they have already started replacing the common identification systems such as bar codes. This paper provides an overview of certain recent radio frequency identification systems and applications patents. An important patent in this field is also discussed at length. The current development constraints as well as a few key future development trends are also mentioned.

Keywords: Radio frequency identification, tags, readers, wireless communication systems, devices, networks, applications.

I. INTRODUCTION

Radio Frequency IDentification (RFID) is a generic term given to wireless systems [1] used to carry data in suitable transponders, generally known as tags, and to retrieve data, by machine-readable means, at a suitable time and place to satisfy certain application needs. Data within a tag usually provide identification (in the form of a unique serial number) of its carrier such as an item in manufacture, goods in transit, a location, the identity of a vehicle, an animal or individual. RFID is grouped under the broad category of automatic identification (Auto-ID) technologies that also include bar codes, optical character readers, retinal scans etc. A typical RFID tag consists of a microchip attached to a radio antenna mounted on a substrate. These kind of tags may even be embedded under the skin. To retrieve the data stored in an RFID tag, one needs a reader which is typically a device with one or more antennas that emit radio waves and receive signals back from the tag. An RFID reader mainly consists of: transmitter, receiver, microprocessor, memory, power, controller and RF communication interface. For the presence of the RF communication interface, RFID systems are mainly non-contact and non-line-of-sight. This means that there is no need to *swipe* the card for an RFID system to identify it.

However, the RFID system as we see it today was not the same when it was invented way back in World War II in 1935 by Scottish physicist Sir Robert Alexander Watson-Watt. With the supervision of Watson-Watt, the British government developed the first active identify friend or foe (IFF) system. The idea was to put a transmitter on each British plane and upon receiving signals from radar stations on the ground; it began broadcasting a signal back that identified the aircraft as friend. This prototype of RFID concept was modified in 1950s and 60s by using radio frequency (RF) energy for commercialization purpose. The first US patent in this field was published on January 23, 1973 for the invention of an active RFID tag with rewritable memory by M. W. Cardullo. That same year, C. Walton received another RFID patent for a passive transponder used to unlock a door without a key. In the recent days, the low power ultra high frequency (UHF) RFID system research has gained a lot of importance after some of the biggest retailers in the world, e.g., Albertsons, Metro, Target, Tesco, Wal-Mart and the US Department of Defense, have said they plan to use electronic product code (EPC) technology to track goods in their supply chain. Interested readers may find a lot more information on the history of RFID in [1] which is beyond the scope of our discussion.

Structurally, there are two broad categories of RFID systems, passive and active [2], depending upon the type of the tags. Passive RFID tags simply reflect back energy (radio waves) coming from the reader antenna. Active tags, on the other hand, have their own transmitter and a power source, usually a battery (active tags could draw energy from the sun or other sources also). They broadcast a signal to transmit the information stored on the microchip. We show the communication process via a passive RFID tag in Fig. (**1**). Please note that an active RFID tag is also similar to this, except for its own power supply thereby enhancing the size and weight of the tag. Certain semi-passive and battery-assisted RFID tags are also there which are suitable for specific applications. It is, however, the requirement of several applications with which different kind of tags are manufactured. For these potential business applications, RFID technology has got much attention of late. These important applications range from manufacturing, supply chain management, retailing, and asset tracking to access control and even convenient payment systems. Apart from these, RFID systems can also be employed for disaster prevention, medical diagnostics etc. To support the needs of all these applications efficiently, different RFID systems have been developed recently along with filing numerous patents over the last few years.

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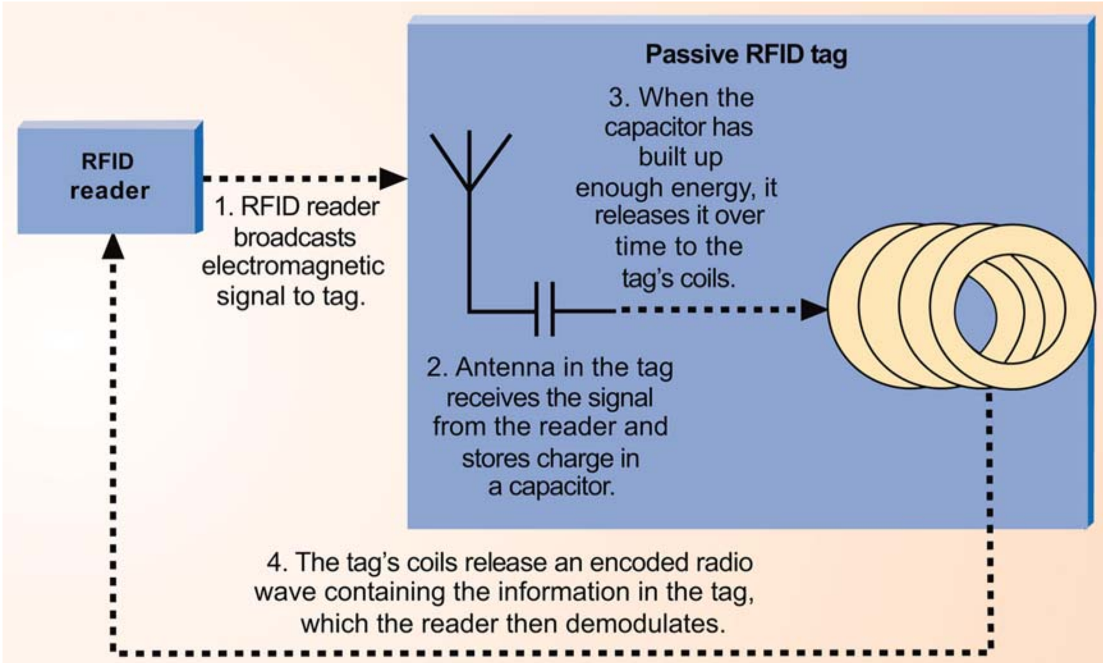

Fig. (1). A simplified view of data communication in low-frequency passive RFID tags (courtesy [2]).

In this survey paper, we focus on a number of patents on RFID systems filed/granted over the last couple of years. We start with a broad overview of numerous patents for RFID systems and devices in Section II and application specific patents in Section III. Section IV discusses at length one of these patents in the possible application area of retailing mainly for the upcoming ultra wideband technology and some important results therein. The paper is concluded with a pinpoint discussion on certain current development constraints and identifying a few future development trends in Section V. Please note that it is not possible to give all the recent patents on RFID within this limited scope. We would thus confine our review only to certain important aspects and applications of this field.

II. PATENTS ON RFID COMMUNICATIONS AND DEVICES

One important focus of recent research in RFID communications and devices has been on low power system implementation with the improvement of several modules to enhance the network accommodation ability along with accuracy and security.

In one such invention [3], an RFID device and locator with wireless communicator system comprising one or more than one antennas for receiving RF signals from one or more RFID tags is discussed. The system has one or more receivers and demodulators for reception and demodulation of signals to baseband signals. A processor circuit processes the baseband signals and provides them to a cross-correlator circuit for cross-correlating the processed baseband signals and for generation of cross-correlated baseband signals. The modulators modulate the baseband signals and provide them to one or more transmitters.

Another work proposes a method [4] for scheduling communications over a wireless communication subsystem and an RFID communication subsystem. The said communication method determines one or more periods of activity of the wireless communication subsystem, derives periods of non-activity on the basis of the one or more determined periods of activity, synchronizes an operation of the RFID communication subsystem with the periods of non-activity and triggers the operation of the RFID communication subsystem. Triggering is done in accordance with the one or more derived periods of non-activity to enable substantially concurrent communications operation of the wireless communication subsystem and the RFID communication subsystem.

In [5], an RFID device is described where a communication and an indication circuitry are mounted within a substrate. The communication circuitry is configured in such a way that it can transmit/receive wireless RF signals including an identifier (say, a control signal). Upon getting the identifier along with the data, the data is written to the data port and the indication circuitry, coupled with the data port, emits a human perceptible signal (i.e., light) to indicate the presence of the data at data port. An exemplary use of such a device may be to assist with the quick identification of a desired package within numerous objects in an inventory.

A different kind of wireless communication device is proposed in [6] comprising of many modules. Firstly, a housing that includes an upper surface, a lower surface, and at least one side intermediate between these two surfaces with a dimension less than smallest dimensions of the upper and the lower surfaces. It also has at least one side surface with visibly perceptible indicia thereon. Next, a communication circuitry is proposed within the housing and the circuitry is configured to communicate wireless signals comprising microwave signals individually having a frequency in excess of about 900 MHz. This communication circuitry effectively deploys an RFID device.

A reconciliation mechanism using RFID and sensors is proposed in [7]. The RFID device, there, is embedded in an

ASIC (application-specific integrated circuit). The device can receive and store digital data from at least one of sensors and aid converter devices. The ASIC includes one or more of the following components: a passive power/communications coupling component with antenna that couples power into the ASIC when employed as a passive device and for facilitating communications with the device when powered, a control module that controls or facilitates the control of all onboard functions, a memory for storing data (e.g., time stamp and event information) and/or programs, a clock for the generation of clock signals and in support of onboard timing requirement and a digital input-output (I/O) interface that facilitates interfacing to digital inputs such as from sensors and/or analog-to-digital converters (ADC). The entire system is shown to work effectively as desired in the context of a medical trial.

In [8], a multi-planar RFID device is proposed. If any RFID tag is flat (with single plane antenna orientation) and parallel to the signal energy field, then the reader can hardly read the data. To solve this problem, this proposal describes a tag that comprises of multi-planar three-dimensional antennas, with perpendicular orientation to each other. This increases the possibility of a positive reading.

In another work, an RFID tag is developed [9] that includes an antenna, a power conversion circuit, a transmit/ receive circuit, a memory device (for storage purpose) and an auxiliary interface device (coupled with an apparatus external to the RFID tag). Here, the memory device is a dual-port non-volatile random access memory connected with a dual-ported multiplexer. The dual-port memory is given importance in this work as the first port is associated with the antenna and the second port is associated with the auxiliary interface device.

Some of the recent works have also focused on RF aerial which is capable of remotely identifying the objects. Such an RF aerial is applied in a wireless communication apparatus in [10]. The radio frequency aerial comprises an identification chip for receiving a radio frequency identification signal. It, therefore, not only transmits general radio frequency communication signal, but also the radio frequency identification signal. A product data stored in the identification chip thus can be directly transmitted to an exterior reading device via the radio frequency aerial and radio frequency identification signal without further setting up a chip aerial. With this aspect, not only the RFID and communication ability of the exterior reading device and identification chip is improved, but the aerial design of the identification chip and setting cost is also simplified.

In [11], an antenna for an RFID system is disclosed where the antenna is basically a loop antenna with a radiating element that comprises two different shaped segments. Each segment is spatially displaced from the other. However, they are electronically interconnected through certain junctions. Actually, the loop antenna is designed in such a way that it increases the effective RFID coverage. On the other hand, it doesn't have a highly complicated structure and it is cost efficient too. The authors have also worked with a multi loop antenna with two radiating elements, spatially displaced from each other and coupled by an electronic coupler, in a different patent [12].

One promising communication technique for developing future retailing, however, lies with the UHF and ultra wideband (UWB) techniques with RFID as said earlier for their capability of processing data at a very fast rate. One such UWB communication is applied to RFID in [13]. In this proposal, a reader generates a UWB infra-red (IR) interrogation signal and receives a UWB IR reply signal from an RFID tag in response to the interrogation signal. We take up this work in details in Section IV. Another UWB communication patent [14] describes an asymmetric bandwidth communication system, wherein a transponder transmits a time domain carrierless impulse radio (TDCIR) signal in UWB and receives a non-TDCIR signal as a continuous wave. The work also demonstrates resilience against path fading, selective absorption and reflection by physical matters and excellent location determination capabilities.

III. PATENTS ON RFID APPLICATIONS

As said earlier, many important business applications for RFID techniques are possible that range from manufacturing, supply chain management, retailing, asset tracking to access control and even convenient payment systems. Apart from these, RFID systems can also be employed for disaster prevention, medical diagnostics etc. We record some of these prominent applications below via several recent patents on RFID.

A. Asset Tracking

An asset tracking system is described in [15] including a computer network that supports a plurality of wireless links from respective wireless access points of said computer network. Mainly a system is designed with a transponder detectable by the wireless access points of the computer network, where the transponder transmits identification information in accordance with a wireless network protocol in response to an interrogation signal. The signal is from one of the wireless access points of the computer network and is stored in one of the networks and transponders. This means the location of the transponder is resolved based on signals communicating the identification information to wireless access points of the network. A mechanism is also provided for accessing and reporting through internal network wireless access point. A wireless device associations including geographic information system is also proposed that resides on or can be downloaded to a terminal of said computer network.

Another asset tracking system in the form of automatic data collection is proposed in [16]. In the invention, the system reads data encoded in data carriers located inside enclosed environments, such as RFID tags attached to objects located in enclosures like buildings, shipping containers, transportation vehicles and other enclosures. The enclosures have dimensions that normally exceed the read range of the RFID tags, and/or the enclosures are composed of materials (such as metal) that impede communication of signals with external RFID readers. Therefore, internal antenna systems are provided in the proposal inside of the enclosures to relay interrogation signals from RFID readers to the RFID tags, and to relay response signals from the RFID tags back to the RFID readers.

Asset tracking inside a carrier whose structure has a plurality of cells are provided in [17]. Here, the corresponding plurality of objects having data carriers, such as radio frequency identification tag, is placed in each cell. Each cell has an indicator associated therewith and is defined by walls that substantially prevent waves (such as RF waves) from propagating between cells. A control module is coupled to the carrier structure and is operative to activate individual ones of the indicators selectively. An automatic data collection device (such as an RFID reader) interrogates the data carriers of the objects placed in the cells, and the data carriers can provide response signals to the data collection device. The control module also monitors the response signals using an antenna present in each cell. If the data collection device selects a particular one of the responsive data carriers, the data collection device provides a notification signal to the control module to notify the control module of the selection. The control module then identifies and selects the cell of an object of interest having the selected data carrier affixed thereon, and initiates activation of the indicator associated with the selected cell, thereby identifying the location of the object of interest.

Two specific asset tracking systems have been published in two recent patents where the first one deals with a method of marking and identifying a gasket [18], and the other one proposes an apparatus for monitoring a tire pressure [19]. In [18], the method comprises of providing a radio frequency identification device of a suitable size and configuration for a particular task at hand, attaching at least one such RFID to the gasket to be marked and identified and subsequently interrogating the RFID by means of a suitable reader to thereby obtain identifying information about the gasket. An RFID system is used in [19], wherein a pressure and a temperature of a tire is constantly monitored for a driver to predict a dangerous situation that may occur in a future and to take a prompt action on the predicted dangerous situation is disclosed.

B. Supply Chain Management and Retailing

One interesting proposal [20] provides retailers, distributors, purchasers, end users and others in a commercial product's distribution chain with systems and methods for product activation at a specific point in the distribution chain (such as at the point of retail sale), for product validation and/or product maintenance (e.g., when the product is brought in for service or maintenance) and for product authentication (e.g., upon resale of the product). These capabilities, when added to the basic capability of an RFID-based system to provide an identity and a location for a tag attached to an object, endow commercial products with functionalities such as theft deterrence, product tracking and inventory management, inventory control and perimeter security, product maintenance and record keeping of service. It also provides a method of easily identifying a genuine item from a counterfeit for high-end commercial products.

C. Access and Security Control

An access control proposal, in general, has been taken up in [21] that facilitates operation of systems by managing and authenticating components, including parts and subsystems, present within a system. The invention includes RFID tags individually associated with the components of the system. The RFID tags generally include at least a part number and a serial number for the components. One or more RFID readers communicate with the RFID tags via a wireless communication medium, where, in particular, a controller generates interrogatory signals, receives response signals from the RFID tags, and employs the received response signals to authenticate the components.

An interesting application of access and security control mechanism by using an RFID payment card are disclosed in [22]. The method generally comprises several modules for receiving indicia identifying an RFID card, receiving a request to activate the RFID card and activating the RFID card by associating an initial value with a database record associated with the RFID card. A module receives a PIN associated with the RFID card and profile information and associating the profile information accordingly with the database record. Systems for using RFID cards generally comprise an RFID card, an RFID account associated with the RFID card, a merchant communication module that receives indicia identifying the RFID card and sends a request to activate the RFID card. A central processor or intermediary is also present that receives a PIN associated with the RFID card and a request to activate the RFID card from the merchant communication module.

Another system for reducing the risk of unwanted scanning of an article comprising an RFID circuit, wherein the RFID circuit comprises a data circuit is presented in [23]. The system includes an RFID chip, an antenna for receiving and emitting radio frequency signals from an external RFID scanner, a connection joining the antenna and the RFID chip and an environmentally sensitive switch in communication with at least one part of the RFID circuit such that the RFID scanning of the circuit is substantially disabled when the state of the switch is off, and enabled when the state of the switch is on. Here, the state of the switch is determined by an environmental factor that can be selectively controlled by a user.

A wireless access point that acquires and processes RFID information is proposed in another patent [24]. The wireless access point may be coupled to a network of RFID readers over a wireless network. The RFID readers may read a plurality of RFID tags and transmit information to one or more readers. The readers may, in turn, transmit the RFID information to a wireless access point. The wireless access point may include a middleware layer for performing a variety of RFID data processing functions. In one mechanism, the wireless RFID reader network is used to improve positioning of readers and tags, and includes a GPS system or position assisted GPS system at the reader and/or tag level.

An RFID tag data processing with access control system is described in [25]. RFID tag data read by an RFID reader are filtered by a filter module mounted on a mobile terminal according to filtering configuration. According to the results of the filtering operation, an address value of a content server is obtained from a connection data server. The address obtained from the connection data server is used to access the corresponding content server, thereby enabling a user to access necessary contents.

D. Disaster Prevention

An apparatus, with such an important application of disaster prevention is proposed in [26]. It is installed in a facility including an RFID tag that stores at least one of a first data and a second data. The first data is related to the disaster prevention, and is transmitted by wireless communication. The second data is related to the disaster prevention, and is received by wireless communication.

E. Medical Diagnostics

This application is also coming up very fast and already a few countries have started using RFID in this field. In [27], an integrated passive wireless chip diagnostic sensor system is described that can be interrogated remotely with a wireless device such as a modified cell phone incorporating multi-protocol RFID reader capabilities (such as the emerging Gen-2 standard) or Bluetooth, providing universal easy to use, low cost and immediate quantitative analyses, geolocation and sensor networking capabilities to users of the technology. The invention presented in [27] can be integrated into various diagnostic platforms and is applicable for use with low power sensors such as thin films, MEMS, electrochemical, thermal, resistive, nano- or micro-fluidic sensor technologies. Applications of this proposal include on-the-spot medical and self-diagnostics on smart skin patches, point of care (PoC) analysis, food diagnostics, pathogen detection, disease-specific wireless biomarker detection and remote structural stresses detection. It can also be used with sensor networks for industrial or homeland security using low cost wireless devices such as modified cell phones.

F. Networking

Usually, the application of networking is taken care by improved reader functionality for peer-to-peer communication. In two such works [28,29], methods and apparatuses for detection of a preamble portion of a data packet is presented. A plurality of samples are received in an input signal. Samples that occur between consecutive sign changes in the received plurality of samples are counted. The counting of samples is performed a number of times to produce a sequence of counts of samples between consecutive sign changes in the received plurality of samples. Matched filtering of the sequence of counts of samples is performed to determine whether a preamble is detected. Bit rate and timing are initialized for data decoding based on parameters of the sequence of sample counts of a detected preamble.

Another mechanism takes up the methods, systems, and apparatuses for mobile devices and antenna thereof [30]. A mobile device includes RFID reader functionality, and functionality for communicating with one or more wireless networks. A single antenna of the mobile device accommodates the network communication functionality and the RFID reader functionality. The communications network is any type of communications network, including a personal area network (PAN), a local area network (LAN), a wide area network (WAN), or a cell phone network. An antenna pattern of the antenna may be configurable. For example, a gain of the antenna may be varied, the antenna pattern may be shaped, directed, polarized, and/or the antenna pattern may be steered. The antenna pattern may even be ranged.

Data carriers (such as RFID tags) are formed into clusters of data carriers in another application [31]. Each cluster has at least one bridge data carrier that can communicate with a bridge data carrier of another cluster, thereby allowing data carriers in each cluster to communicate directly or indirectly with each other using a stochastic communication protocol method. Direct tag-to-tag communication capability is provided between data carriers in each cluster and/or between clusters. The data carriers can backscatter and modulate a carrier wave from a source, thereby using the backscattered and modulated carrier wave to convey data to each other.

IV. DETAILED DISCUSSION ABOUT A PATENT

Let us consider a scenario where a major retail chain is tagging all its goods in all its stores at the single item level. The number of tagged items in this scenario can easily reach several billions. This means that the data identifying these billions of items amounts to many gigabytes (assuming 12 bytes per tag). All these mountains of RFID data need to be synchronized, filtered, analyzed, managed, and acted upon, often in real-time or near real-time. Each tag is then essentially a single computing device, albeit a very simple one, which acts as one node in a network of billions of such devices. This new network is dramatically different and in many ways more complex than even the Internet, the most complex network ever known. This fact is due primarily to the number of nodes that could exist in the expanded model of a worldwide RFID network, which figures to be several orders of magnitude larger than the number of nodes on the Internet, meaning traditional computing architectures and infrastructures will not be adequate to handle the dramatically higher data volumes expected in such a network. One aspect to solve this is to use a high speed data transfer with peer-to-peer communication to perform RFID-related data processing locally. The current RFID systems should take care of this point to proliferate retailing business globally. We overview one such patent [13] at length in the following.

A. The Patent US20077154396 (2007) [13]

UWB techniques cover a frequency band usually from 3.1 GHz to 10.6 GHz. This pulse-based wireless communication technology has numerous advantages including low cost, low power consumption, high penetration ability, high data rate and high security (extremely narrow pulse width and low duty cycle cause the UWB signals to be spread over a wide bandwidth resulting in extremely low power spectral densities over GHz bandwidth and increasing the security). These are the main reasons why the biggest retailers of world want to track goods in their supply chain with RFID using this technique. However, for UWB transmission, the spectral density has to be under -41 dBm/MHz and the utilized bandwidth has to be higher that 500 MHz. To facilitate this, impulse radio (IR) is one practical technique where data transmission is usually done by short baseband pulses that are separated by suitable time gaps. Therefore, IR neither uses a carrier signal nor it is affected by multipath propagation severely.

In the patent US7154396, the author has proposed an RFID reader that generates a UWB IR interrogation signal and receives a UWB IR reply signal from an RFID tag in response to the interrogation signal. In addition, the reader may generate a baseband response sequence from the UWB IR reply signal. This sequence includes at least a tag identifier. A reader may store at least a tag identifier. Upon receipt of a UWB IR interrogation signal, the tag obtains a plurality of clock pulses from the UWB IR interrogation signal. Based on the plurality of clock pulses, the reader transmits at least the tag identifier in a UWB IR response signal. Block diagram of an exemplary UWB transceiver as well as the RFID reader for this scheme is shown in Fig. **2**. The transceiver includes a transmitter, a receiver, transmit/receive switch, a band pass filter (BPF) and an antenna. When the Tx/Rx switch is connected with the Tx, UWB impulses are sent from an impulse generator, based on the symbols received from a symbol source. When the switch is connected to Rx, the amplified received UWB signal (after passing through low noise amplifier (LNA)) is mixed with a template generated by a template generator. The integrator accumulates the output of the mixer to generate an analog signal which is finally converted to a stream of digital symbols by ADC. When this total module is connected via a controller and a memory, the entire block becomes the RFID reader. Such a reader can then communicate with a plurality of tags. Tags usually exchange information with a reader in a manner that involves the reader issuing an interrogation signal having multiple clock pulses. In response, the tags send information (e.g., tag identifiers and/or data) to the reader. The manner in which the information is sent to the reader is guided by these clock pulses. If the tag is a passive or semi-passive one, then it receives the power usually from the interrogation signal.

The main advantage of such an impulse radio RFID system is that the separation between the transmitted interrogation signals and the received response signals is enhanced in this scheme, making it possible to locate the tags sufficiently at a moderate distance from the reader. The scheme, in fact, works both for long and short range distances.

V. CURRENT & FUTURE DEVELOPMENTS

Although RFID has promising applications in supply chain management, a number of challenges have hampered the adoption of RFID globally. These challenges can be broadly classified as technological, standard and business challenges [32]. Technological difficulties mainly include antenna orientation of tags and probability of collision made

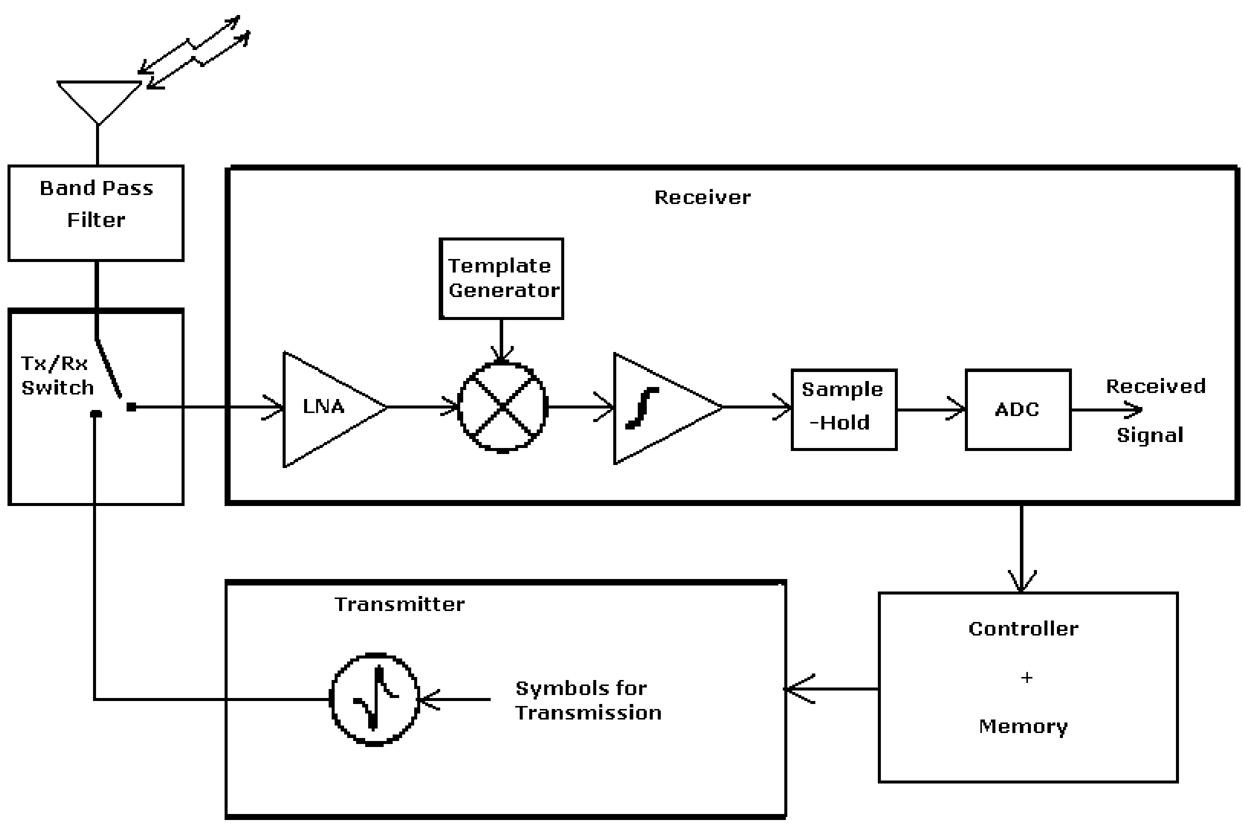

Fig. (2). Block diagram of an exemplary UWB transceiver as well as the RFID reader as proposed in [13].

by simultaneous radio transmission, hampering the reliability of the system. Standard challenge, which is one major point, is mainly caused by lack of unification and spectrum allocation. Another point is business challenge where a lot of issues like cost challenge, infrastructure challenge, return on investment challenge are involved. Among these, overcoming the cost challenges is a hot issue which has already been covered in detail by a white paper "Towards Five-cent Tag" by S. Sarma in 2001. All these challenges should be taken up one-by-one to make this technology a wide success.

Till the date, RFID, its application, standardization, and innovation are constantly changing with different new methods. Its adoption is still relatively new and hence there are many features of the technology that are not well understood by the general populace. Developments in RFID technology continue to yield larger memory capacities, wider reading ranges, and faster processing. True, it's unlikely that the technology will ultimately wipe out bar code because even with the inevitable reduction in raw materials coupled with economies of scale, the integrated circuit in an RF tag is less expected to be as cost-effective as a bar code label. Nevertheless, RFID will continue to grow in its established niches where bar code or other optical technologies aren't effective. If some standards commonality is achieved, whereby RFID equipment from different manufacturers can be used interchangeably, the market will very likely grow exponentially. It is thus expected that RFID spectrum allocation and regulations will be made unified and globally interoperable across different countries. Once RFID systems prove to be effective and economical within companies, interoperable RFID systems across companies might proliferate soon. However, apart from all these technical advents, there also exists another side of RFID chips related to human beings that has recently been discussed in [33]. It's true that deploying implantable RFID chips in human body has many advantages like permanently having biological identity or information that can be used anytime, anywhere, but it also violates the right to bodily integrity of human being. The better idea is always to examine all the pros and cons of this upcoming technology carefully before adopting it directly for the human kind.

REFERENCES

[1] A guide to understanding RFID [Online]. Available: http://www.rfidjournal.com/article/gettingstarted/.

[2] Weinstein, R. RFID: A technical overview and its application to the enterprise. IT Professional 2005; 5: 27-33.

[3] Feher, K.: US20070032250A1 (**2007**).

[4] Honkanen, M., Junell, J., Lappetelainen, A.: WO07060494A1 (**2007**).

[5] Trosper, S. T.: US20070035395A1 (**2007**).

[6] Tuttle, M. E.: US20077221257 (**2007**).

[7] Streeb, M., Winzinger, S.: US20070018819A1 (**2007**).

[8] Kovac, F. G., Craig, J. J.: US20070029385A1 (**2007**).

[9] Hammond, W. A., Willke, T. L., Posamentier, J.: US20070075139A1 (**2007**).

[10] Yen, L., Fang, C.-H.: US20060202011A1 (**2006**).

[11] Qing, X., Chen, Z., Cai, A.: WO07058619A1 (**2007**).

[12] Qing, X., Chen, Z., Cai, A.: WO07058620A1 (**2007**).

[13] Reunamaki, J.: US20077154396 (**2007**).

[14] Pahlaven, K., Eskafi, F. H.: US20077180421 (**2007**).

[15] Moody, J. O., Steinbrecher, E. R.: US20077256681 (**2007**).

[16] Kodukula, V., Nikitin, P.: US20070001809A1 (**2007**).

[17] Maltseff, P. A., Payne, R. D.: WO07035833A2 (**2007**).

[18] Corbett, Jr., B. G.: US20077158034 (**2007**).

[19] Park, J. S., Oh, H. R., Goyang, Kim, J. O.: US20070013502A1 (**2007**).

[20] Jedrey, T. C., Archer, E.: US20070109103A1 (**2007**).

[21] Ghosh, D.: US20077239242 (**2007**).

[22] Chakiris, P. M., Smith, M. B., Lowin, L.G.: US20060231611A1 (**2006**).

[23] Lindsay, J. D., Velazquez, H. F., Chen, F.-J., Wagner, E. F., Onderko, J. C.: US20070152829A1 (**2007**).

[24] Shoarinejad, K.: WO07056333A2 (**2007**).

[25] Min, S. C., Kim, H. S.: US20070120647A1 (**2007**).

[26] Saga, S., Kawaida, Y., Kaneko, H.: US20060226970A1 (**2006**).

[27] Peeters, J. P.: US20060290496A1 (**2006**).

[28] Okunev, Y., Maizenberg, V.: US20070071036A1 (**2007**).

[29] Okunev, Y., Maizenberg, V.: WO07037956A2 (**2007**).

[30] Wulff, T., Knadle, Jr., R. T.: US20070141997A1 (**2007**).

[31] Maltseff, P. A., Winter, S., Nikitin, P., Kodukula, V., Erosheva, E.: WO07035863A2 (**2007**).

[32] Wu, N.C., Nystrom, M.A., Lin, T.R., Yu, H.C. Challenges to Global RFID Adoption. Proc PICMET, 2006, 618-623.

[33] Foster, K.R., Jaeger, J. RFID Inside. IEEE Spectrum 2007; 3: 24-29.