AN OVERVIEW OF BACK SCATTERED RADIO FREQUENCY IDENTIFICATION SYSTEM (RFID)

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Abstract: Radio frequency identification (RFID) system is a wireless communication system in which the radio link between the base station and the transponders are furnished by the modulated back-scattered waves. The present paper is intended to provide a description of various subsystems of the RFID in brief. The various applications of RFID are discussed. Sample results on read /write range for transponder designed at 2.45 GHz are also discussed.

I. Introduction: Radio frequency identification (RFID) system is a wireless communication system in which the radio link between the base station and the transponders are furnished by the modulated back-scattered waves. RFID is an intelligent barcode system. This system has few advantages over conventional barcode system. However it should not be interpreted that RFID is a complete replacement to barcode until it gets inexpensive in the market place. RFID is certainly a useful alternative identification tool in applications where large data storages are essential. Few advantages of RFID over barcode are:

- It does not require the transponder to be in line-of-sight.
- Multiple tag identification is possible.
- RFID can handle environments like moisture, dirt frost etc.
- We can combine the RFID functionality with Electronic Article Surveillance (EAS)

The RFID can be operated at ISM bands without any license. A special site license can be obtained from the regulatory authorities for high power applications. RFID can be widely used in the applications like retail, transportation, access control, asset management, supply chain, electronic anti theft. Few promising applications are source tagging, self check out, video rental, parking, auto registration, non-stop toll collection, access control, badge readers, subway entry, theme parks, warehouse inventory, package handling, parcels, mail, pallets etc.

The frequency of operation used in RFID ranges from very low (few kHz) to 5.0 GHZ. In particular, systems at 13.56 MHz, 400 MHz, 915 MHz, 2.45 GHZ and 5.3 GHz are in use. Most of the systems are based on the principle of modulated back scattered signal detection. The basic sub systems of RFID are base station module, computer control unit and the transponder consisting of a printed antenna and an integrated circuit with memory and processing unit. Some recent developments on transponder chips have shown the capability of read/write functionality. The information on the chip can be reprogrammed or the data can be handled in a convenient way useful to automatic data control applications. Such functionality is extremely difficult or impossible with the present barcode system.

For example a back-scattered RFID system developed at both 900 MHz and 2.45 GHz at Intermec Technologies Corporation has the following key features:

1. A single programmable chip with low power digital circuitry together with schottky diodes.
2. Identify and communicate with multiple tags in the field.
3. Read from and write to individual tags.
4. Broadcast information to all tags in the field.
5. Permanently lockable memory
6. Select a subgroup of tags to identify or communicate based on information stored in the tag.

The following sections are devoted to describe some of the performance characteristics of the base station reader module, transponder antenna and the principle behind the back scattered signal detection with passive tags and a brief description of the processing integrated circuit system. Few results on the range performance for a sample tag are discussed. Photographs of other components of the RFID system are also shown for better understanding.

II. System Description: A back-scattered RFID system has a RF base station module, computer controller, an RF transponder and a detecting and processing unit attached to the transponder in the form of a chip (Refer Figure 1.). A basic block diagram of the RFID system is shown in Figure 2. The base station has a micro-controller module, DSP module, radio module and a circularly polarized base station antenna pair. The system uses frequency-hopping spread spectrum. FCC 15-247 type of approval is required in USA with an EIRP of 36 dBm. European regulations have different EIRP allocations. The modulated signal from the base station is received by the tag transponder that can be either active or passive. Voltage induced at the input terminals of the transponder due to the RF field from the base station. This voltage will be detected by the RF front end circuit of the chip and this DC voltage will be

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used to charge a high capacitor and provide the necessary bias for the processing circuitry. The basic circuit representation for the transponder is shown in Figure 3. The response of the transponder is determined by the voltage induced on the transponder that exceeds a threshold voltage, which depends on the properties of the detection circuit attached to the transponder antenna. The induced voltage is computed with the assistance of radar equation and a series of coordinate transformations. At a given point in space, an induced voltage is calculated from the field produced by the base station antenna pair and the effective antenna height of the transponder under consideration. The relation of induced voltage, chip impedance, EIRP ($G_{tx} P_{tx}$) from the base station and the range can be expressed as [1]

$$G_{tx} P_{tx} = \frac{R_L}{2G_{rcv}} \left(\frac{V_{th}}{2}+V_{on}\right)^2 \left(\frac{4\pi r}{\lambda |Z_L|}\right)^2 \qquad \ldots (1)$$

where

$G_{tx} P_{tx}$ is the EIRP of the system regulated by FCC.
Z_L ($R_L + jX_L$) is the RF impedance of the chip.
V_{on} is the cut in voltage of the front-end diode
V_{th} is the threshold voltage of the chip to respond.
G_{rcv} is the gain of the transponder antenna.

The processing circuit on the chip responds to the base station commands according to the protocol and provides a change in the in the RF impedance and hence provides a detectable back scattered signal to the base station. Depending on the sensitivity of the receiver and the minimum transponder threshold voltage we can establish a read /write range from the base station. Data can be either read from any memory location of the chip or can be written to any specified location.

A typical value of R_L is low and is of the order of 18 ohms. The maximum permitted gain from the base station antenna is 6 dBi linear. The transponder tag antenna can be designed to provide the required range performance to induce the threshold voltage at the input of RF front end. For a dipole the maximum range at 2.45 GHz is of the order of a meter. However the important point in the design is the matching between the front end and the input of the tag antenna terminals. A careful matching network design is the key for obtaining the best performance.

One of the most important characteristics of a RFID system is its "read zone", which is defined as the volume inside which the base station can communicate with the transponders (or, tags). The details on the calculation of the read zone are explained in a separate communication.

RFID transponders have at least two basic components. First, is the ASIC and second, is a printed circuit board substrate with tag antenna artwork. The circuit artwork consists of an etched or printed antenna and ground on a number of substrate possibilities (polyamide, polyester, paper, FR4, etc.).

The ASIC is attached between the tag antenna input ports using various packing techniques like i) wire bonding ii) Surface mounting (SMT) and iii) Flip-chip technology. Few techniques using wire bonding are Chip-on-board, chip-in-board and chip-on-flex *etc.* These techniques are discussed in separate communication. The following section gives a few details about the tag integrated circuit developed at Intemec Technologies Corporation.

III. RFID Tag Integrated Circuit System :

This chip has several features that make it an excellent solution for many types of RFID. Some of the fundamental improvements that the recent technology has over previous RFID chips are the inclusion of the detector diodes and clocking circuitry in the chip. In most RFID systems there is an ASIC that is supported by peripheral electronics. These extra parts may be batteries, crystals, resistors, capacitors, transistors and diodes. All add complexity and cost to the resulting tag. All the functions required for RFID in a tag are contained within the single chip. This results in a simpler and more reliable overall tag. This simplicity leads to lower price points and added ease of installation.

The basic components in the chip are (Figure 4.):

- EEPROM
- RF front end
- Analog section
- Digital Section
- Storage device / battery

Typical chip specifications are:

1. Ultra low power 5-15 micro-watts during read operation and 80-120 micro-watts during write operation
2. Forward and return links use different types of modulation schemes.
3. EEPROM total 128 bytes.
4. System reserved memory 8 bytes.
5. Tag identifier (ID) 8 bytes.
6. User memory 112 bytes.
7. Operating temperature –40 to 175^{0}C

The chip is made of silicon and hence it contributes to the cost of the transponder. Future developments in this area could be focussed to reduce the cost of the chip and increase the processing power and memory.

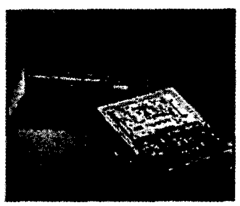
IV. Results and Discussions :

There are various types of both active and passive back-scattered tags are available in the market place at various frequency ranges. Active tags provide longer read ranges. However these tags could be expensive due to the requirement of batteries. The passive tags do not need any battery and hence they provide an inexpensive solution. The passive tags at lower frequencies provide longer ranges at the cost of large form factors. They also provide longer ranges due to the fact that higher quality factors can be obtained at low frequencies. The only limitation at low frequency is that the tags are prohibitively longer due to the requirement of length comparable to wavelength On the contrary the form factors of tags at high frequencies like 2.4 GHz and 5.3 GHz are small and may provide an inexpensive package costs. These tags provide reasonable read /write ranges of the order of 1 meter. A sample results on read/write range for a dipole tag as a designed at 2.45 GHz are shown in Figure 5 as a function of rotation angle in a plane perpendicular to the axis of the tag.

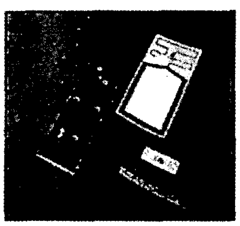
References:

1. Notes from Dah-Weih Duan ,IBM Research P.O.Box 219, Yorktown, N.Y,10598,1998.

(A) Processing Chip



(B) Base station Module



(C) Transponders

(D) Base Station Antenna

Figure 1. RFID System Components

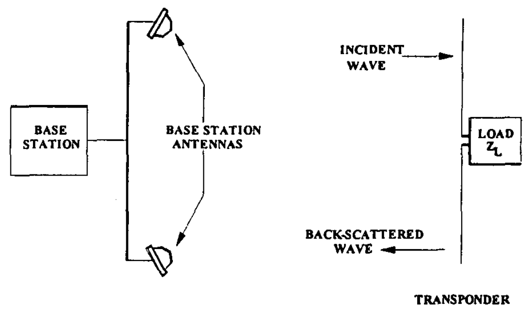


Figure 2. Block Diagram of a Back-scattered

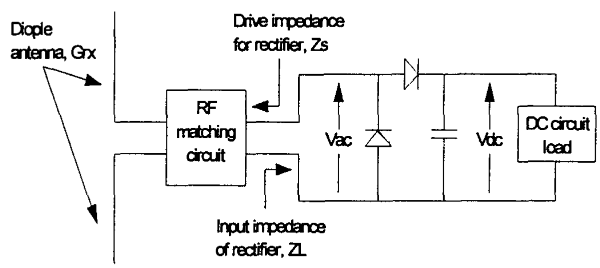


Figure 3. Circuit Representation of the Transponder

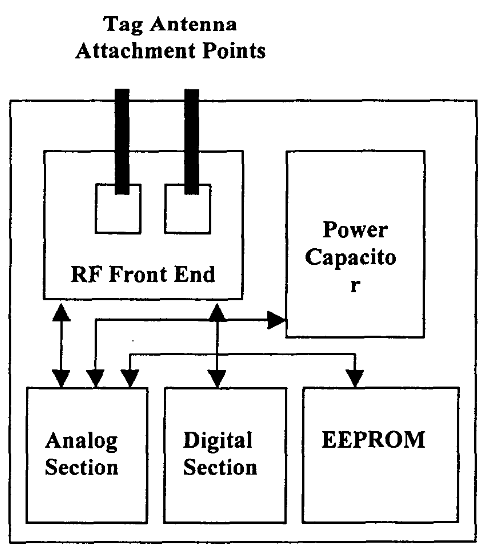


Figure 4. RFID Tag Integrated Circuit Block Diagram

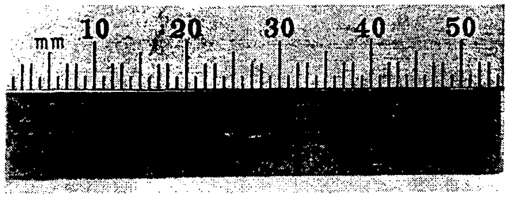


Figure 5 (a) Dipole tag at 2.45GHz

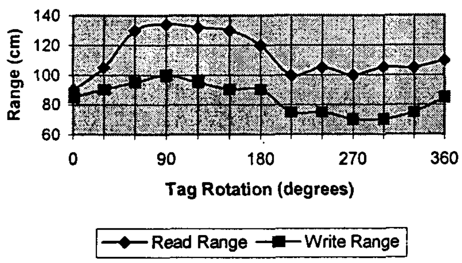


Figure 5(b). Transponder Read/ write Range Pattern