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Radio-Frequency Identification Systems

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Abstract

Radio-frequency identification (RFID) is one of the most enabling technologies that continues to be considered in numerous applications. It is basically a wireless system exploiting the principle of communication by reflected waves. This paper reviews the principle ofRFID systems, and discusses the main characteristics. Since the tag is the most constrained device in RFID — since it is usually does have a battery, and is quite versatile and low cost — the paper reviews different tag designs, as well as some advan results and proposals.

I. Introduction

E. Perret The history of radio-frequency identification (RFID's) birth and development has been described in numerous publications [1-4, 13]. It is generally said that the principle of RFID communication was presented by H. Stockman in 1948 [5], and the first application was the identity friend or foe (IFF) system [4] introduced and developed by Watson-Watt.

The IFF system consisted of a transmitter embedded on each aircraft. When it received signals from ground radar stations, it began broadcasting a signal back that identified

the aircraft. This signal was due to the reflection of the plane, and depended on its size and shape.

RFID works on the same principle. A signal is sent to a transponder, which wakes up and either reflects back a signal (passive system), or broadcasts a specific identification signal (active system).

Advances in RF communication systems and radar continued through the 1950s and 1960s. Researchers and engineers worldwide presented many papers explaining howRF energy could be used to remotely identify objects.
RF. Harrington developed the electromagnetic theory
only the presence or the absence of a tag could be detected [1]. In the 1970s, and under the impulse of microelectronic technology, companies, universities, and government laboratories were actively engaged in the development of practical applications of RFID.

Thousands of applications can be found in the literature [8]
, among them animal tracking, toll roads, vehicle identification, factory automation, access control, identity papers, and logistics. Even if the interest was different

between Europe and the US, the 1980s was the decade for mass deployment of RFID technology

. The interest in the US was mainly for transportation and access control. In Europe, the greatest interests were for animal tagging, industrial applications, and toll roads

. Since the 1990s, many technological developments have dramatically expanded the functionality of RFID. Advances in microelectronics, embedded software, and RF/ microwavecircuit integration are opening the doors to new RFID application

.

2. Rfid System Architecture

Any RFID system is composed of three main elements, as depicted in Figure 1. The most important element is the tag or transponder, which contains the information, or at least a part of it. The second element is the reader or the interrogator and its antenna. The latter can be integrated into the reader, or can be separated from the reader. The RFID reader emits a radio signal at a fixed frequency, which is used to power up the tag, and communicates with it using the backscattering technique. The third element is usually the database for the application, which can be of varying sizes and sophistication, depending on the processed data and security constraints. In some specific applications, the database is integrated into the reader. Due to RF signal properties, the reader is able to communicate through a large variety of material and obstacles, including conductors, but under restricted configurations in terms of positioning. This reading ability over a wide range of propagation conditions differentiates RFID from optical barcode, andthus explains the huge interest for many applications.

RFID is fundamentally wireless communication, using radio waves of the electromagnetic spectrum. It operates in the unlicensed part of the spectrum known as ISM (industrial, scientific, and medical). The frequency, power limitations, communication protocols, and standards can vary for different regions in the world. This is particularly true for RFID in the UHF band. The operating frequencies are grouped in different bands. The data rates and reading ranges are quite different from one band to another. Table 1 summarizes the RFID bands and some of their practical characteristics.

RFID is a very specific technology that obeys a number of standards and regulations. There are many other wireless technologies, such as ZigBee, Bluetooth, Wi-Fi, and, more recently, UWB. These technologies are designed for very different uses and therefore have different functionalities; however, there is shared ground among all. Applications based on "mixing" these technologies are beingdeveloped in many labs. Among them, the real-time locating

systems (RTLS) [14] and the Internet of Things (IOF) [10]are exploiting RFID properties.

3. Rfid Tags

The tag is certainly the most important element in any RFID system. Even if the overall performance of the application depends on the characteristics of each component, the performance of the tag is the limiting parameter. Most of the constraints are applied to the tag. This leads to a large variety of tag architectures, with quite different physical shapes and electrical configurations. In

all cases, the tag is mainly composed of two elements:
the

antenna, which ensures wireless communication, and adevice that memorizes the information. The latter can be an optical barcode, but do not require line-of-sightcommunication, and thus can be interrogated over obstacles.

Passive, low-cost tags are of great interest in numerous applications. Considerable advances have been made in the design of these tags, but there is still very active worldwide research and development, in order to improve the performance, lower the cost, and implement new applications. We should make a distinction between LF, HF, and UHF tags. Indeed, for LF and HF tags and readers, the metallic strap that is the interface between the integrated circuit and the reader strictly speaking is not an antenna, but a coil. The physical principle of data transfer is not based on propagating electromagnetic waves, as in UHF, but on thevariation of the quasistatic magnetic or electric field.

Signaling between the reader and the tag is done in several different incompatible ways, depending on the frequency band used by the tag. Tags operating on LF and HF bands are, in terms of radio wavelength, very close to the reader antenna because they are only a small percentage of a wavelength away. By switching between lower and higher relative loads, the tag produces a change that the reader can detect. At UHF and higher frequencies, the tag is more than one radio wavelength away from the reader, requiring a different approach. The tag can backscatter a signal. Active tags may contain functionally separated transmitters and receivers, and the tag need not respond on a frequency related to the reader's interrogation signal.

RFID systems can be classified by the type of tag and reader.There are 3 types:

A **Passive Reader Active Tag** (**PRAT**) system has a passive reader which only receives radio signals from active tags (battery operated, transmit only). The reception range of a PRAT system reader can be adjusted from 1–2,000 feet (0–600 m), allowing flexibility in applications such as asset protection and supervision.

An **Active Reader Passive Tag** (**ARPT**) system has an active reader, which transmits interrogator signals and also receives authentication replies from passive tags.

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