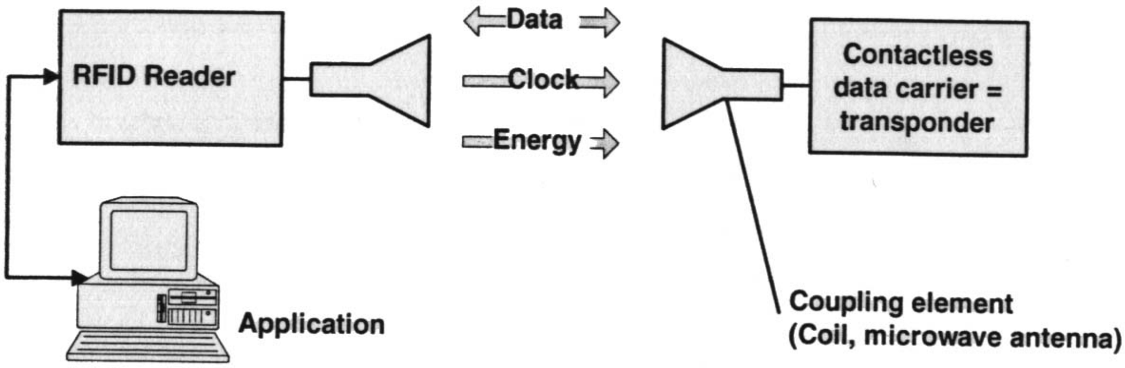
2 An Introduction to RFID Technology

A RFID systems comprises of the following components:

- A transponder (or tag), which is the object to be identified.
- A reader (or interrogator), which may be read only (RO), or Read Write (RW) depending upon the technology.
- An antenna for reception and transmission.

The function of each component may vary between systems, but basically perform in a similar manner. Since data is gathered for use in computer-based systems, usually the reader/interrogator interfaces to a PC or a network of server-clients, eventually connected to the Internet.



Basic RFiD system

2.1 Reader

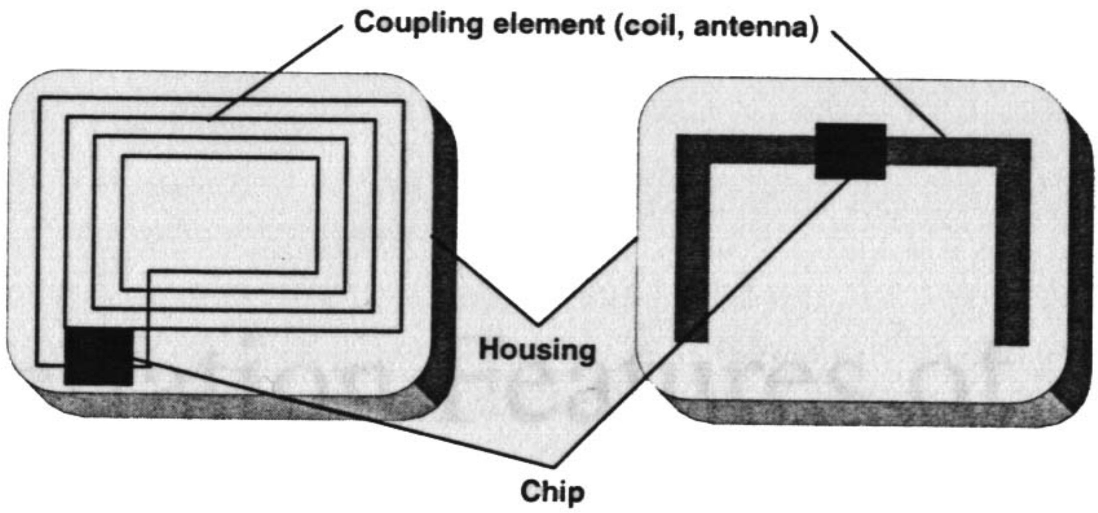
The reader/interrogators can differ quite considerably in complexity, depending upon the type of tags being supported and the functions to be fulfilled. However, the overall function is to provide the means of communicating with the tags and facilitating data transfer. Functions performed by the reader may include quite sophisticated signal conditioning, parity error checking and correction. Once the signal from a transponder has been correctly received and decoded, algorithms may be applied to decide whether the signal is a repeat transmission, and may then instruct the transponder to cease transmitting. This is known as the "Command Response Protocol" and is used to circumvent the problem of reading multiple tags in a short space of time. Using interrogators in this way is sometimes referred to as "Hands Down Polling". An alternative, more secure, but slower tag polling technique is called "Hands Up Polling" which involves the interrogator looking for tags with specific identities, and interrogating them in turn. This is contention management, and a variety of techniques have been developed to improve the process of batch reading. A further approach may use multiple readers, multiplexed into one interrogator, but with attendant increases in costs.
A reader typically contains a radio frequency module (transmitter and receiver), a control unit and a coupling element to the transponder (antenna). In addition many readers are fitted with an additional interface (RS232 or RS 485) to enable it to forward the data received to another system (PC, embedded system, etc).

2.2 Antenna

The antenna emits radio signals to activate the tag and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system data acquisition and communication. Antennas are available in a variety of shapes and sizes; they can be built into a door frame to receive tag data from persons or things passing through the door, or mounted on an interstate toll booth to monitor traffic passing by on a freeway. The electromagnetic field produced by an antenna can be constantly present when multiple tags are expected continually. If constant interrogation is not required, the field can be activated by a sensor device.
Often the antenna is packaged with the transceiver and decoder to become a reader/interrogator, which can be configured either as a handheld or a fixed-mount device. The reader emits radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and the radio frequency used. When an RFID tag passes through the electromagnetic zone, it detects the reader activation signal. The reader decodes the data encoded in the tag integrated circuit (silicon chip) and the data is passed to the host computer for processing.

2.3 Transponder

The transponder, term derived from TRANSmitter/resPONDER, represents the actual data carrying device of an RFID system, and normally consists of a *coupling element* and an electronic *microchip.* When the transponder, which does not usually possess its own voltage supply (battery), is not within the interrogation zone of a reader it is totally shut off. The transponder is only activated when it is within the interrogation zone of a reader. The power required to activate the transponder is supplied to the transponder through the coupling unit (contactless) as is the timing pulse and data.

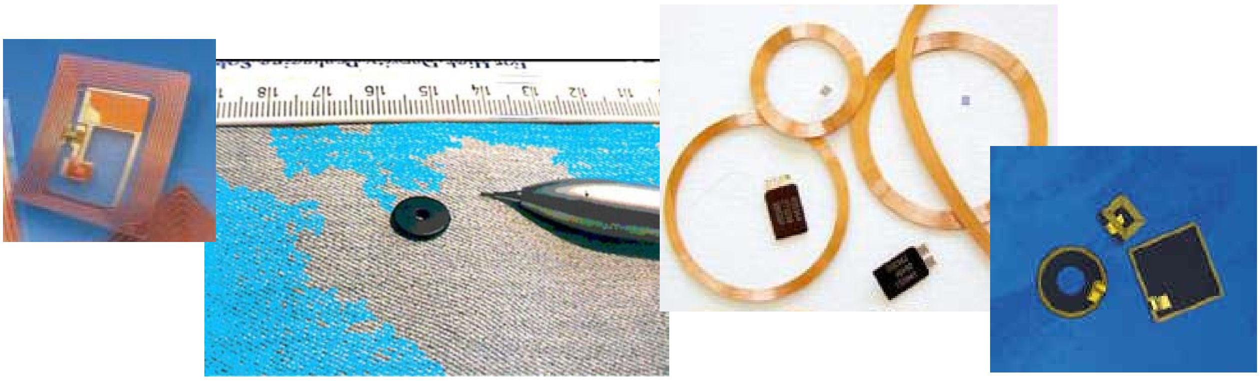


Basic layout of the RFID data carrying device, the transponder. Left: Inductively coupled transponder with antenna coil, right: Microwave transponder with bipolar antenna.

RFID transponders exist in countless variants, produced by an almost equally high number of manufacturers.

They can be grouped into three basic packaging types

- Tags – ampoules, coins, pills, “stick”, key fob
- Cards - credit card size (the already addressed contactless smart card)
- Smart Labels – printed label with an RFID tag embedded. They are thin, flexible, disposable.



Some samples of commercial transponders

If we are to maintain an overview of RFID systems we must seek out features that can be used to differentiate one RFID system from another. These features can mainly identified in the following:

2.4 Data capacities of RFID transponders –

The data capacities of RFID transponders normally range from a few bytes to several kBytes. So-called 1-bit transponders represent the exception to this rule: a data quantity of exactly one bit is just enough to signal two states to the reader: “transponder in the field” or “no transponder in the field”. However this is perfectly adequate to fulfil simple monitoring or signalling functions. Because a 1-bit transponders does not need an electronic chip, these transponders can be manufactured for a fraction of a cent of Euro. For this reason vast number of 1-bit transponders are used in *Electronic Article Surveillance* (EAS) to protect goods in shops and businesses. If someone attempts to leave the shop with goods that have not been paid for the reader installed in the exit recognises the state “transponder in the field” and initiates the appropriate reaction. The 1-bit transponder is removed or deactivated at the till when the goods are paid for. Transponders with data capacity up to 128 bits are used for storing identification or serial number, together with one bit for parity check. These devices can be programmed both by the manufacturers and by the users. Tags with data capacity up to 512 bits are always user-programmable and suitable to store identification data as well as other specific information as serial number, process instructions, and results of most recent transactions. Tags with data capacity of about 64kBits can be regarded as carrier for portable data files. Higher data capacity also allows to organise data in records or pages that can be selectively accessed during the reading process. Depending on the tag memory characteristics it is also possible to identify *read-only* tags, *WORM* (write once read many) tags, and *read/write* tags.

2.5 Possibility of writing data –

In very simple systems the transponder data record, usually a simple (serial) number, is incorporated when the chip is manufactured and cannot be altered thereafter.

In writeable transponders, on the other hand, the reader can write data to the transponder. Three main procedures are used to store the data: in inductively coupled RFID systems EEPROMs (electrically erasable programmable read only memory, non volatile memory) are dominant, however these have the disadvantage of a high power consumption during the writing operation and a limited number of write cycles (typically of the order of 100,000 to 1,000,000). FRAMs (ferromagnetic random access memory) have recently been used in isolated cases. The read power consumption of FRAMs is lower than that of EEPROMs by a factor of 100 and the writing time is 1000 times lower. Manufacturing problems have hindered its widespread introduction onto the market as yet.

2.6 Power supply to the transponder

RFID tags are categorised as either active or passive. Active RFID tags are powered by an internal battery and are typically read/write, i.e., tag data can be rewritten and/or modified. An active tag memory size varies according to application requirements; some systems operate with up to 1MB of memory. In a typical read/write RFID work-in-process system, a tag might give a machine a set of instructions, and the machine would then report its performance to the tag. This encoded data would then become part of the tagged part history. The battery-supplied power of an active tag generally gives it a longer read range. The trade off is greater size, greater cost, and a limited operational life (which may yield a maximum of 10 years, depending upon operating temperatures and battery type).

Passive RFID tags operate without a separate external power source and obtain operating power generated from the reader. Passive tags are consequently much lighter than active tags, less expensive, and offer a virtually unlimited operational lifetime. The trade off is that they have shorter read ranges than active tags and require a higher-powered reader. Read-only tags are typically passive and are programmed with a unique set of data (usually 32 to 128 bits) that cannot be modified. Read-only tags most often operate as a license plate into a database, in the same way as linear barcodes reference a database containing modifiable product-specific information.

2.7 Frequency of operation

Choice of field or carrier wave frequency is of primary importance in determining data transfer rates. In practical terms the rate of data transfer is influenced primarily by the frequency of the carrier wave or varying field used to carry the data between the tag and its reader. Generally speaking the higher the frequency the higher the data transfer or throughput rates that can be achieved. This is intimately linked to bandwidth or range available within the frequency spectrum for the communication process. The channel bandwidth needs to be at least twice the bit rate required for the application in mind. Where narrow band allocations are involved the limitation on data rate can be an important consideration. It is clearly less of an issue where wide bandwidths are involved. Using the 2.4 - 2.5 GHz spread spectrum band, for example, 1 megabits per second data rates may be achieved, with added noise immunity provided by the spread spectrum modulation approach. Spread spectrum apart, increasing the bandwidth allows an increase noise level and a reduction in signal-to-noise ratio. Since it is generally necessary to ensure a signal is above the noise floor for a given application, bandwidth is an important consideration in this respect. The previous considerations, along with the fact that transponder working in high frequency, so communicating by means of transmitted waves rather than by inductive link, are often active devices, make every frequency range suitable for particular applications.

There are basically four main frequencies of operation for a RFiD system:

- Low Frequency (<135KHz)
- High Frequency (13.56MHz)
- Ultra High Frequency (433 MHz, 860MHz, 928MHz)
- Microwave (2.45 and 5.8 GHz)

And these systems have the following features:

2.8 Data Capacity.

This is the measure of data that the tag can carry, and is given in bits. E.g. a 1kbit tag is able to carry 128 characters.

2.9 Read-write or read only (RW/RO)

Read only tags have to be programmed at the factory and carry the identification number. Read/write tags can have their contents updated in the field, however there may be a limit to the number of RW operations possible for a particular tag memory technology.

2.10 Transfer rate.

The rate at which the tag data is transferred to the reader unit, this is usually expressed in bits per second.

2.11 Read (and write) time.

This is linked to the transfer rate, but with the time overhead of any communications management protocols. In a multiple tag environment, the read time must be multiplied by the number of tags to be read. There is an issue when the tags are not able to communicate with the reader, or that the read zones are restricted, then the read time becomes crucial and the faster the better. Another factor that has to be included is the amount of data to be transferred, and if all the tags data has to be transmitted at any one time. With RW tags, the write time can be significant for the successful transfer of data.

2.12 Range.

This is defined as the distance that the tag can be reliably read/written to by the reader/programmer. The main factors affecting range is the transmission power and frequency, and these are both regulated by national and international regulations.

2.13 Read accuracy and repeatability.

Below are the main factors that affect accuracy and the success of reading a tag.

- Orientation – is the tag more sensitive to a particular orientation when in the field of the reader.
- Anti-collision and multi-tag environments – can many tags be read when they are all in the field of the reader, using an anti-collision algorithm to ensure that only one tag responds to the reader field at one time.
- Obstacles – the field may block the field, especially if the obstacle is ferrite based. The field will not be linear and 'blind spots' can reduce the effectiveness of the reader.

- Sources of interference – other electrical equipment maybe produce interference that will affect the reader field and reduce the read range and accuracy/repeatability.

2.14 **Tag shape and robustness.**

Tags can be formed in many different shapes and their robustness is dependant upon their ‘carrier’ or encapsulation.

2.15 **Cost**

Part cost for the tag, reader or read/writer.

Case Study

K FI Trading, an Italian company, applied RFID technology in the supply of a system for identification and process control of items of clothing in a commercial laundry system.

The company selected a 13.56 M Hz passive RFID technical solution. The technology selection was influenced by the following factors:

- The high temperature and other environmental factors of the application made the provision of a battery operated system infeasible from a safety and operational cost perspective. In practice it was also considered too costly on a per unit basis to adopt active RFID technology solutions, and impractical to fix using sewing methods to the clothes.
- The required system needed to be able to discriminate between many items closely packed together. This required an anti-collision capability for the tag and a larger reading distance. A 13.56 MHz system provided a better read range and the anti-collision facilities required in the ISO specifications.
- The antenna size and construction for a 125 KHz system which required a larger coil winding made the technical implementation of the antenna on a printed system less practical. The 13.56 M Hz technology adoption allowed the use of a printed substrate antenna.

Finally, it should be noted that the technology selection also considered alternative solutions such as bar coding. The exposure to extreme washing cycles and the need to handle clothing to read these labels meant such solutions were not viable. However, this process of evaluation is a preliminary stage towards the selection of RFID technical solutions.

Case Study:

Free2Move, a Sedish company, implemented a system for securing the cool-chain of transported sensitive goods using active RFID tags and readers. As the company noted "Radio Frequency Identification (RFID) is not a well-defined concept but rather a name of different technologies used for labeling objects and to communicate the identity information over a wireless media. The possibility to communicate information stored in the tags gives rise to many new applications."

This case study identifies the comparison between active and passive RFID tag technologies undertaken by Free2move for their application. The system requirements were determined to be:

- Capability to read and write information to the tag in a multi-tag environment.
- Ability to log temperature at arbitrary points in time
- Ability to position the tag with sub meter accuracy
- A tag life of approximately 2 years with enabled logging function
- Approximately a 10 meter range to the reader

The final implementation was based on the 2.4 GHz ISM band instead of lower frequency bands. The rational behind this choice was that the channel capacity of 1 Mbit/sec provided the ability to address approximately 1,000 previously unknown units per second. In practice there was no upper practical limit to the number of tags that can be addressed in the neighbourhood of the reader. The Active vs. Passive RFID tag selection was based on the following limitations of the passive solution:

Short range

With antenna design giving reasonable form factors one cannot expect a range over 1 meter, often much less, with standard passive RFID tags.

Limited channel capacity

The inductive or capacitive transmission mechanism limits the capacity today to about 20 Kbit/sec. This constituted a severe limitation regarding the number of tags that can be read per time unit.

Form factor of tag design

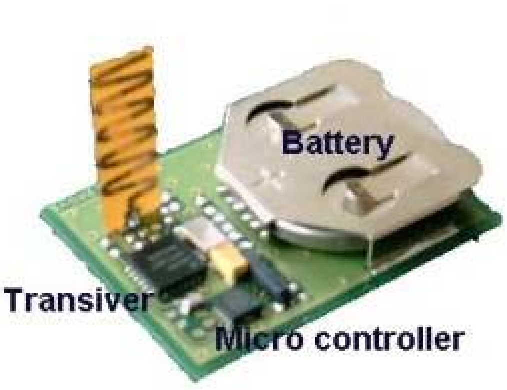
The antenna of the passive tag has to have a certain dimension in order to power the circuits on the tag. This is a hurdle for designing small tags.

Power consumption of the reader

The power loss when transferring energy from the reader to the tag is high. This results in high power consumption in the reader. In many mobile applications the reader is battery powered causing problems with short battery life.

No operation outside the reader field

No processing can be performed when the tag is outside the reader field. This is a major drawback for surveillance applications where the tag is performing some kind of logging. In our case this is directly disqualifies the passive technology.



System Tag and Reader Units

	RFiD technology (by carrier frequency)			
	Low frequency	**High frequency**	**Ultra high frequency**	**Microwave**
Data Capacity (tag type)	Typically. 64 bits to 2kbits. (Passive or active)	Typically 512bits to 8kbits. (Passive or active)	Typically 32bits to 4kbits. (Passive or active)	Typically 128bits to 32kbits. (Passive or active)
RW /RO	Both available	Both available	Both available	Both available
Transfer rate	Typically 200bits/s to 1kbit/s	Typically 25kbits/s to 100kbit/s	Typically 28kbits/s	Typically 100kbits/s to 1Mbit/s
Read (and write) time	Typically 0.5s[1]	Typically 2ms[2]	Typically 2ms[3]	Typically 0.05s[4]
Range	Near contact, or up to 0.5m, for an active tag	1.2m for RW , 1.5m for RO passive tags	1.2m for RW , 1.5m for RO passive tags	1 to 2m for passive tags, active tags > 10m
Accuracy and repeatability	Single tag and multi tag anti-collision systems	Single tag and multi tag anti-collision systems. Better noise immunity than low frequency systems	Single tag and multi tag anti-collision systems.	Single tag and multi tag anti-collision systems.
Tag shape and robustness	Wide variety available, but susceptible to low frequency interference	Wide variety available, including smart cards and smart labels. Rigid and flexible substrates available	Wide variety available	Wide variety available, including smart cards and smart labels. Rigid and flexible substrates available

[1] 96bits transferred at 200bits/s
[2] 512bits transferred at 26kbits/s
[3] 512bits transferred at 28kbits/s
[4] 32kbits transferred at 100kbits/s

	RFiD technology (by carrier frequency)			
	Low frequency	**High frequency**	**Ultra high frequency**	**Microwave**
Costs	Dependant upon tag shape and application, typically used in systems where tag: reader is < 30:1	Dependant upon tag shape and application, e.g. Smart labels cost = 30 cents.	Dependant upon tag shape and application, e.g. Tag cost = 40 cents	Dependant upon tag shape and active or passive operation
Application areas	Access control, animal identification, vehicle and container identification and manufacturing support	Airline baggage management, library systems, parcel tracking and supply chain logistics	Asset tracking and supply chain logistics	Factory automation, access control, road tolling and supply chain logistics