Short Report to FhG-Report RFID 01/2012

RFID, a key technology for a transparent building construction and a lasting facility management (RFID-Sensor: Energy-Hygiene-Safety)

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1. Aim of the research task

In the context of the research initiative „Zukunft Bau“ the Federal Ministry of traffic, building and urban development (BMVBS) sponsors through the Federal Office of Building and Environmental Planning (BBR) projects for the consortium (ARGE) to the application of the electronic identification of building products and systems with the help of RFID technology [1]. This consortium „RFID im Bau“ consists of the Fraunhofer-Institute for Building Physics (IBP) and Fraunhofer-Institute for Microelectronic Circuits and Systems (IMS) with the teaching and field of research area building business and building construction of the Bergisch University of Wuppertal [2], the faculty building engineering, professorship construction process technology of University of Dresden [3], the institute for numeric methods and computer science in the building and construction industry of the Technical University of Darmstadt [4] as well as various industry companies, see joint web page www.rfidimbau.de (Fig. 1).

Fig. 1: Logo of the project community „ARGE RFIDimBau“

It is the primary aim to achieve a cost optimization and improving quality of buildings with the help of RFID technology. Each of the project partners examines the potentials of the RFID technologies in single projects in his competence area and in a common coordination with today's building processes.

In a first project of the Fraunhofer-Institute for building physics (IBP) „RFID- indicators and building quality“ the construction phase was primarily in the foreground [5]. There was to represent and to show the bases of the RFID application in building physics, how is to create an increased transparency by an electronic identification by means of different RFID transponders to essential parameters from components and the building. Passive RFID transponder technology was examined with local data structures for the exemplary characteristic value inquiry from single components at the example of the façade. The possibilities of an automated building documentation with the description of making physical debit to actual states were represented. So information deficits shall be avoided, building quality increased and costs lowered between the building ones involved.

The second Fraunhofer project with the short title „RFID sensor: Energy –Hygiene - Safety“ has the main emphasis in the building use phase. The aspects of the making physical use of components and their life cycle are in the foreground here differently than in the first Fraunhofer project. So dynamic information about the current condition of single components and building systems shall be recorded and weighted with the help of the RFID-wireless- and sensor-technique. So after the building construction in the long-standing use phase we are able by „looking“ into the parts of the building to get a safeguarding of the quality. The Fraunhofer IBP worked on the partial topics of specific values and quality characteristics of components to exemplary applications in the area of energy, comfort, hygiene and safety of constructions. RFID technology and

sensor transponder, IT connection with standardization, hierarchical combinations and IT additional functions were the partial topics of the Fraunhofer IMS. The putting into action possibilities for dynamic component-/ building construction data for one so-called „Building monitoring"was examined together with the ARGE RFIDimBau.

Within the last few years the microelectronics developed rapidly, primarily the possibility of saving data on microchips in a decentralized system and of data readout with mobile readers. Digit rates of some MB per second are standard [6] today and represent the base for the possible applications in the building and construction industry. Helmus in [7] has represented the bases by the acquirement of a building logistics control post in the area of the goods and staff logistics. The application of RFID-technique in the building shell for a so called „intelligent component" with a de-central data management Jehle examined [8]. No sensors were, however, integrated into the RFID transponders for the condition recording yet. But the information chain from the building product planning about the production and logistics until the use in the building e.g. is based on the same data set. So it was obvious to include a possible condition change of the components by sensors in the transponders. For a short time, e. g. such sensor transponder systems are commercial in the motor vehicle industry for the tire pressure or temperature monitoring in use [9].

Therefore the task of the Fraunhofer IMS also consisted in the customization and realization of RFID sensor system for the applications described in chapter 5 and 6. Sensor solutions for the following examples have arisen:

- Passive sensor transponder for the measuring of temperature and internal pressure in a Vacuum insulation panel (VIP) and therefore for the supervision of the usability in built-in condition without a wired monitoring.
- Passive sensor transponder for the measuring of humidity and temperature e. g. in ceilings and walls to the identification and assessment of building parts with humidity critical areas and conditions.
- Active sensor transponder (sensor net) for the continuous recording of different physical measurands in buildings. Examples to this are the temperature and pressure measuring in control units of solar plants, the determination of temperatures and dew water in components of the building envelope or of deposit in ventilation lines.

The work carried out and results obtained are described in the Fraunhofer report RFID 01/2012 exemplarily. The basic principles for the RFID technology are in the chapter 3 listed commonly. Chapter 4 explains the fundamentals and advantages of the sensor transponder technology. Chapter 5 describes general applications of the RFID technique in the construction engineering while chapter 6 and 7 is explaining the applications investigated by Fraunhofer IBP and IMS of RFID technology with sensors in the building engineering.

Necessary technology, the requirements for the application and the exemplary realization as model-like demonstration are respectively described. First results from the practice with references to the building suitability and to the data security are showcased in chapter 7. An estimate to the quality management at dealing with RFID technology, the costs and the integration into future projects are represented in chapter 8 and 9.

2. Execution of the research task

It was agreed within the ARGE RFIDimBau that every institution independently works on her partial projects and one regularly informs each other about the essential results. This was carried out in the ARGE meetings, see in [1], category „Internal" with coordination by the spokesman of the ARGE and with information about the project accompanying steering circle. From these coordinations the common activities like presentation of the project results at fairs and conferences are worked out, also the combination of the partial results to a common so-called „Interface project".

The results from the first Fraunhofer project showed that the at that time and for the project start of the second Fraunhofer project available RFID transponders with sensors and the corresponding data readers it were not making fit. Therefore a current enquiry for suitable hardware components and the adaption of the IMS sensor transponder systems for the proposed applications were necessary. The first investigations could be made in the test facilities and climatic chambers of Fraunhofer IMS and later in the climatic chambers and on the test façades of Fraunhofer IBP in real building condition range of -25° Celsius to +40° Celsius.

Further enquiries for the integration of user interfaces between the RFID systems and usual building software with the requirements on the data management gave the description of the integration in Facility management systems (FM). Available Reader and storage devices usage for construction work were coordinated with the reader protocols for the needed sensor tags.

This hardware was exemplary to test for the applications in the areas of energy/ VIP, Hygiene/ ventilation line and safety/ timber building system e.g. through:

- Conception and construction of adapted hardware modules (transponders, tag readers, measuring and calibrating facilities) and function models,
- Conception and construction of small demonstrators,
- The prooftesting of the hardware at and in the building,
- Construction of samples in the test façade,
- Multiple tests with differently trained users for the recording of improvement potentials.

For the achievement of objectives as more transparency and traceability of building physic characteristics we reflected results of the project „Safety coefficients in the thermal protection according EnEV/BRL and EN standards (SiWaS)" [10]. Forecast values are examined there for characteristic values like the Thermal transfer through envelope parts of a building with mathematical methods [11]. However, these characteristic values should be coupled with the data to their derivation and identification to be able to make quality-related statements. How this can to be connected with RFID technology is shown in the Fraunhofer report RFID 01/2012 in chap. 6.3 theoretically; a possible putting into action in the practice is explained in chap. 9.4.

From examinations to the software integration in building control systems (GLT) or building automation systems (GA) knowledge could being won for the further development in future projects together with converters (Chap. 7).

3. Combination of the results

In the long run the wishful thinking of client and investors is to make buildings technically of high quality and without faults, to operate these damage freely and economically and to living and working in this cosily. The aim of the project is therefore supporting building lastingly in technical and ecological quality by electronic identification and monitoring systems. To this two groups of influence sizes have to be taken into account. At first aspects of the durability, of existing quality safeguarding systems, the building business quality and the building efficiency (build energy efficient efficient technical building equipment). An improvement in the transparency of the building processes and the buildings itself can be reached with that. On the other hand, the availability of the equipment and sensors for a component recording and component check, its costs and the handling and acceptance in the building and construction industry in the context of the project had to be examined.
The established instruments of the public contracting are not yet technically orientedly and hardly comprehensibly like the pre-qualification and identification of economic quality (i. e. a process optimization as building and operating in quality- and costs-frame). Primarily data to the workmanship of different construction methods with different building products are over the business and life cycle of spaces and buildings little available and most planners and operators unknown. No sensibility to better building quality can arise and the multi use of higher-order building products and constructions the mostly small and medium-sized enterprises at the making as well as the property developers (also public hand!) is not being shown.
But definitely the static information (like the construction of a part of a building with his basic components) together with the dynamic information (like the one to the drying or condensation properties) are the data which are strongly different in the course of the use of a building construction. The original properties in new condition change fundamentally depending on the material type and quality by usage, ageing, weathering, humidity load or pollution.
Only with obviously assignable information about the essential actually built-in products and the debit-being in comparison of the planned data with the results carried out such proofs can lead about database systems, such as to the energy demand/ energy consumption. The technique of the RFID-Ident identification offers profitable and practice fit solutions to this. Technical systems for the recording of the condition of components or building construction already are present for the measuring of temperature, pressure, humidity by radio sensor technique with RFID identification.
Prototypes are verified in laboratory models and examined in real buildings at test façades or in the validity check (IBP Stuttgart, IMS Duisburg/ inHaus1). Test applications for sensor RFID transponders for the component qualities like strength or stretching can be realized, first measuring systems are built up and are in the laboratory test. At concrete building physical applications for the facility management the advantages and chances of RFID technology could be shown in the interaction with the retrofitting of buildings e.g. in refurbishments.

The examination methodology was to show in the 3 example areas of energy, hygiene and safety some technical applications in building physics.

In the **area of energy**, this is represented at the example of a façade with a glass panel with VIP insulation as a test scenario. The VIP internal pressure-measuring method is represented wirelessly integratedly now as a monitoring method in the LF radio engineering with a direct measurement

procedure instead of with an auxiliary method. This therefore represents a quality safeguarding method and allows an in situ component check over long time periods. Time periods are striven for considerably more greatly than 10 years, in the context of the project long-term tests were already carried out more than 2 years. Use of such a system therefore provides a higher product safety. From this advantages arise for manufacturers of the VIPs, user/investor and building supervision by after-testable results to the condition of the VIP insulation. Results over the medium term are economic advantages by a lower pre-hold measure in the assessment of the safety to the energy and humidity prtection of such building constructions with VIP insulation.

The LF pressure sensor prototype has further been optimized by tests into pressure chambers in the IMS. The process of calibrating at the production of VIP pressure sensor transponder and the VIP components itself with integrated sensor transponders could be made marketable, results were visualised.
Wireless sensor net systems for the obtainment of higher reaches are available e.g. for the monitoring of building conditions in roofs and façades. These distances of over 5 meters reach in the frequency domain of the mobile radio engineering at 2,4 GHz. These so-calledly active sensor transponders in network knot technology need a battery of their own and were tested as prototypes. You also have been available as commercial system such components since some months. The building product qualities such as temperature, light, humidity, smoke, presence and air pressure can be determined and checked with that.

First examples of the application to the **topic hygiene** are shown. The regular supervision of the condition of ventilation lines or facilities to the controlled apartment ventilation like outer wall ventilator or heat exchanger with regard to her hygiene condition are ascertainably with the RFID sensor technique, e.g. to dew water content, contamination etc. From this the compliance with maintenance and cleaning interval or the supervision of dew water formation at thermal bridges can take place automatedly.

In the **topic safety**, systems were examined to the over-capability of the origin and the quality of building products, for condition control of automated façade components particularly RWA elements and fire protection elements. And for a preventive, indirect identification of wear limits due to excessive warming or to high component humidity was carried out particularly for wood constructions in inaccessible places as roofs (monitoring system). Examples to this are shown. The suitable RFID sensor technique can be used with the LF humidity sensor tag (available as an IMS prototype). The tests of such a VIP pressure- and humidity-sensor showing the operation over a year at the demonstrator building „InHaus-1“ in Duisburg.

Within a building physical application we needed the necessary data flow and combination models with the multilayered data but you can indicate these only in the project and they are to develop together with software companies. Spot solutions for component and building system supervisions with RFID sensors are introduced and offered commercially already for over one year.

In the first Fraunhofer-RFID project „Indicators and building quality“ the potential of integration of slim supervisory systems of building components with RFID-tags and post-connected software modules is shown. Primarily the modular construction by standardized protocols and interfaces on the information way from the RFID-tag to the user makes a variety of uses of these data by

new services possible. Ideas are introduced to this in the areas of Facility management (FM), building instrumentation and control (GLT) or building automation (GA). The automated preparation of the building energy card is a good example in future for innovative developers as integrated with wireless RFID sensor technology in building constructions like façades or roofs new added value services can offer.

Mainly in the environment where no MSR technology is existing and simple recording system would be enquired for a house automation (e. g. for sensors at heating components, circulating pumps, fire protection installations, windows). These then can be integrated into sensor nets to FM systems; Suggestions to this are described. For the putting into action of the ideas of application easy understandable demonstrators were exemplary built up.

Some possibilities of the presently available RFID sensor hardware are shown with that in the building application and with the improvement potential. The impulses for need assessments to a construction-specific hardware development can be estimate from this. Further examinations to the efficiency and usability of the series models for sensor RFID transponders to be developed from this should take place in the planned interface project in the consortium „RFIDimBau". Into this the proof then can be furnished that the quality of the sensor data (precision, drift, reproducibility) is sufficiently enough over long time application in the component for the made requirements under usual boundary conditions in buildings (handling, building environment like dust, water, humidity, temperature, pushes etc.) also about this one. Qualitative notes are shown by the confrontation of previous recording systems in a QFD analysis with assessment together with estimates for the cost reduction about series effects and to batteryless systems.

Unfortunately, the first commercial RFID sensor components were only 2011 available for the data acquisition about a larger distance of some meters (active transponders with memory and controller as well as tag readers) shortly before project end. These shall be tested 2013 in cooperation with the VIP manufacturers and further industry partners and the RFID sensor data into the software package „RFID-kiosk" being integrated completely. This RFID technique then can be integrated in the building business with such „intelligent" networking sensors to the building product level. So the long-term research objective can be reached to provide the decision maker, investor and user of the rooms with the won information about the building component condition and therefore the quality standard wirelessly. The forecast for the project continuations going on at present and to ideas of project shows the further putting into action potential from the project „RFID-Sensor: Energy-Hygiene-Safety".

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