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RFID SENSOR SYSTEM EMBEDDED IN CONCRETE –VALIDATION OF UHF ANTENNA GEOMETRIES IN DIFFERENT CONCRETE DEPTHS

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1. Introduction

This paper is a further research on the topic of the complete embedding of radio frequency identification (RFID) sensors in concrete [1]. The focus is on the antenna of the transponder. Earlier investigations of different RFID technologies, embedded in concrete, showed a difference in energy transmission [2]. The transmission through concrete at ultra high frequency (UHF), in spite of the large signal range, does not match the targeted application specific task. Therefore, the antenna characteristics have been examined more closely. The antenna is an important component for the application of RFID. Through the antenna, energy and data transfer takes place, so it is important to design an optimal antenna to accomplish a maximum embedding depths in concrete.

To identify the optimal antenna geometry, different UHF antenna types were selected and investigated. An experimental comparison was performed to gain more information about the damping behavior and antenna characteristics in concrete. Furthermore, Transponders were tested in different construction designs, including rigid and flexible carrier materials, with and without sensor wiring. This paper presents first results.

2. Antenna and Transponder

Fig. 1. UHF antennas.

The investigated antenna geometries (Fig. 1) 1 to 9 are planar antennas on flexible plastic carrier material. The application area extends from Library, to Transportation and Healthcare. Antennas 10a/b are planar antennas, too and the first BAM antenna geometry. Antenna 10a (with sensor) and 10b (without sensor), are $^{\lambda}/_{2}$ antennas, it has been used for the first functional tests of the competed wired sensor system. The carrier material consists of stare FR4 material.

$$\frac{\lambda}{2} = \frac{c}{f} \tag{1}$$

λ = antenna length in meter (for e.g. 868 MHz)
f = frequency in Hz
c = speed of light in m/s

3. Experimental Setup and Equipment

The experiments were carried out in laboratory conditions. Fig. 2 shows the test setup with three floating screed test specimen of 5 cm thickness. As a test system the Voyantic Tagformance Pro (Voyantic Ltd. Finland) was used to investigate the antenna characteristics. The experiment was carried out in four steps. In all measurements, the transponder antenna was positioned at a distance of 100 cm from the reader antenna, to avoid being in the near-field area (Long-range antenna). During the first measurement (reference measurement), the transponder with antenna was applied in the middle of the concrete structures surface, while in the case of further measurements, the transponder was positioned step by step behind a further specimen, resulting in ca. 5, 10, and 15 cm of concrete screed between transponder antenna and reader antenna. This setup approximately represents a real-world scenario, with a number of influences and disturbances from environmental conditions.

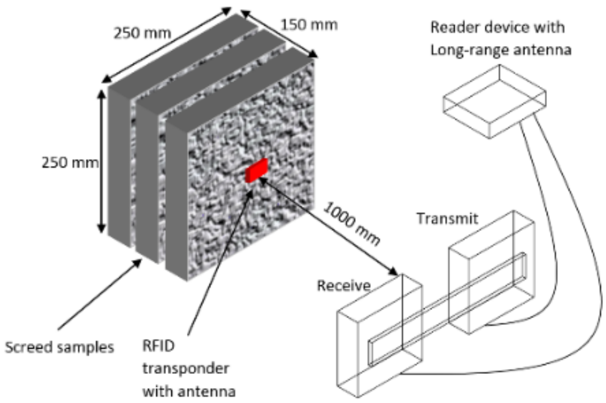

Fig. 2. Experimental concrete setup.

4. Results

The main objective of the study was to find an antenna geometry with minimal required power transmission through concrete thicknesses up to 15 cm and stable transmission performance. Because of issues with reflections, the abstract focuses on results up to 10 cm. All results were averaged over a number of 10 measurements.

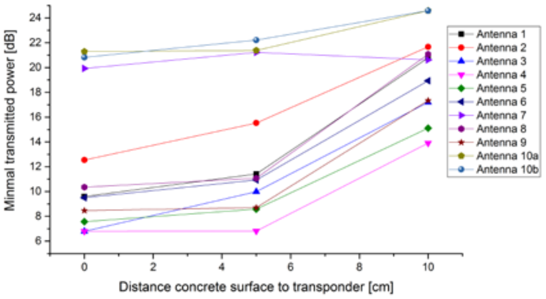

Fig. 3. Minimal required power of all antennas.

Fig. 3 shows the minimal required power to receive a transponder response. Basically, for all antennas the required power increases with additional concrete between transponder and reader. From 10 tested antennas, Antenna 4 enables measurements with the lowest power requirements, qualifying it for further implementation and testing.

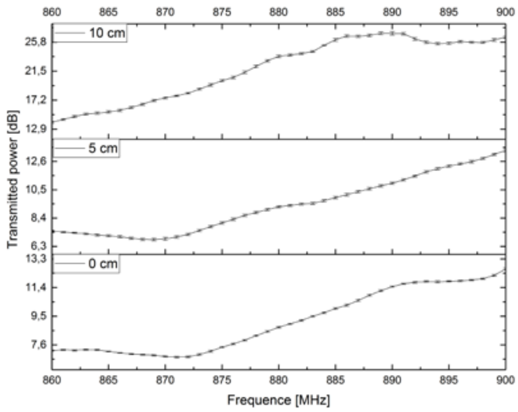

Fig. 4. Frequency response of Antenna 4 and standard deviation behind different concrete thicknesses.

The frequency response of Antenna 4 (Fig. 4) shows best results for frequencies between 860 and 875 MHz, which corresponds well to the European standard operation frequency for UHF RFID systems at around 868 MHz. Error bars indicate the low standard deviation, suggesting a stable transmission performance through different concrete thicknesses and over the whole frequency range.

5. Conclusion

The results show that the antenna geometry has a significant impact on the transmission characteristics through concrete and should be further optimized and validated. Of the 10 investigated antennas, Antenna 4 behaved the most stable and has low damping characteristics for transmission through concrete screed up to 10 cm.

6. Outlook

Fig. 5 shows the first implementation model which derived from this antenna examination. It was etched on a FR4 carrier material, and consists of copper. This antenna will serve as basis to provide sufficient energy transfer to operate the embedded RFID sensors systems [3]. For further optimization, the antenna impedance must be calculated.

Fig. 5. Implementation model of Antenna 4.

Next steps are the simulation of the antenna geometry in combination with electronics and different concrete depths. Further validation tests in real embedding scenarios should show whether the antenna geometry enables good results (a) with fully wired and embedded systems, (b) regarding installation depths up to 15 cm, and (c) for different concrete materials.

References

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[2] Bartholmai, M., Strangfeld, C., Johann, S., Kammermeier, M., Müller, M., RFID sensor systems embedded in concrete – systematical investigation of the transmission characteristics, 8th European Workshop On Structural Health Monitoring, 2016.

[3] Strangfeld, C., Johann, S., Müller, M., Bartholmai, M., Moisture Measurements with RFID based Sensors in Screed and Concrete, 8th European Workshop On Structural Health Monitoring, 2016.