

Development of a dipole antenna sensitive to corrosion of steel

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Summary:

Monitoring corrosion of reinforcing steel is critical for ensuring the durability and structural safety of civil engineering infrastructures. This paper presents a corrosion-sensitive antenna for detecting corrosion of metallic element in free space, serving as a preliminary step toward UHF RFID-based corrosion monitoring systems for civil engineering structures.

Keywords: Corrosion monitoring, steel, dipole antenna, resonance frequency.

Introduction

The service life of reinforced concrete infrastructures is highly dependent on the corrosion resistance of steel. Indeed, in marine environments, carbonation and chloride penetration from the surrounding environment are known to initiate steel corrosion processes, subsequently leading to the weakening of the structure and, eventually, to its collapse. Traditional corrosion detection methods, such as visual inspections, are time-consuming and costly, and do not allow early detection of corrosion, since the steel is inaccessible. Recently, Radio Frequency Identification (RFID) technology has been proposed as an innovative method for corrosion detection. It is particularly attractive due to the small size of RFID tags, their low cost, and their ability to operate wirelessly. Furthermore, the absence of batteries and cables facilitates their integration into concrete during construction or maintenance/repair operations. Over the past several years, we have therefore proposed several solutions to incorporate corrosion-sensing capabilities into RFID tags. In particular, we recently proposed a UHF-RFID sensor based on an additional sensitive metallic layer exposed to corrosion and located very close, in the mm range, to the RFID antenna [1]. This approach relies on the electromagnetic coupling between the antenna and this metallic layer. The principle is straightforward: as corrosion progresses, the thickness of the thin metal layer decreases, leading to an increase in its electrical resistance and, consequently, to a variation in the properties of the coupled antenna.

This method was applied to produce an UHF-RFID sensor embedded in concrete in close proximity to a steel foil which acts as the

sensitive element[2] and more recently to prestressed infrastructures [3]. Despite of the interest of the method, the short-range distance between the antenna and the sensitive material limits the applications. Indeed, due to the aggressive nature of the environment (pH=13), ensuring a long lifetime of an embedded antenna in concrete remains a challenge. Within this context, the use of a remotely located antenna appears to be a relevant alternative. The present work therefore focus on the sensitivity of a dipole antenna positioned in the centimeter range from a steel foil exposed to corrosion. As it will be shown, its performance progressively degrades as corrosion evolves, thereby offering a robust and promising solution for civil engineering applications.

Materials et methods

The development of the dipole antenna sensitive to a distant metallic element was carried out using the ANSYS HFSS software, based on the finite element method with a tetrahedral mesh. The fabricated antenna was produced via a LPKF prototyping machine. Figure 1 illustrates the experimental setup. As observed, an antenna-steel distance $d_{as} = 12$ mm is used, a value which extend the distance currently used in UHF-RFID corrosion sensors. Experimental results were obtained using a steel sheet (300 x 50 x 0.05 mm). Since corrosion is a low process, it is accelerated through sodium chloride deposition, periodic addition of water approximately every 24 hours, and exposure to ambient air. The reflection parameter S_{11} of the antenna was measured using a vector network analyzer (Anritsu MS2037C) connected to the antenna via a coplanar transmission line, then acquired and processed using a computer. On Fig. 1, the

resonance associated with the operating antenna is well observed on the computer.

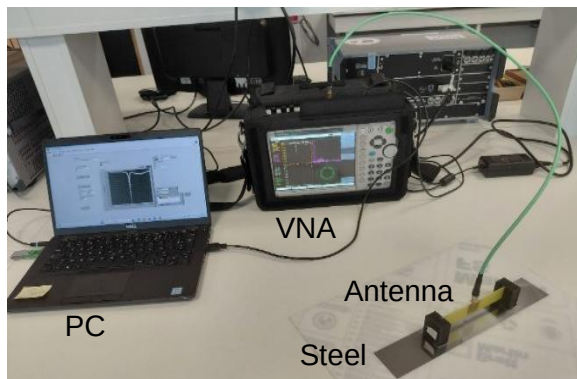


Fig. 1. The experimental setup

Experimental results

Figure 2 displays the S_{11} parameter during corrosion of the steel foil. Before corrosion, in red, a well-defined resonance is observed indicating the good impedance matching of the antenna with the presence of the metallic plate. During corrosion, a degradation of antenna performance is observed, accompanied by a resonance frequency shift associated with the changes in the surrounding environment. This behaviour could be induced by the formation of rust on the steel plate, or due to the presence of hydrated species on the surface. Finally, when the 50 μm of steel are corroded, in yellow color, the antenna does not work properly. The change of operating state of the antenna, is consequently indicative of a mass loss of steel. The inset of Fig. 2 displays the state of the steel corresponding to S_{11} parameter displayed in yellow color.

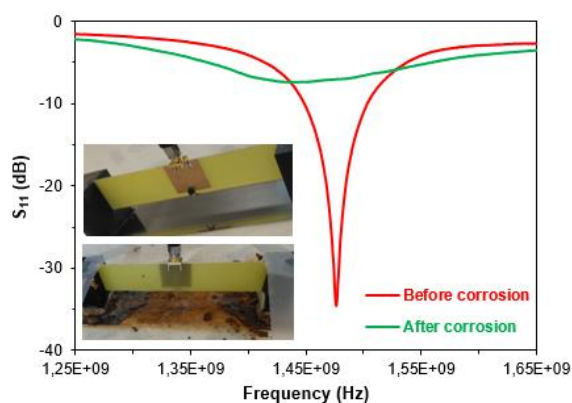


Fig. 2. S_{11} versus frequency during the corrosion of the steel foil. Inset: Steel foil before and after corrosion.

Conclusion

The results demonstrate that monitoring corrosion of a metallic foil is possible when the antenna and the sensitive metallic foil are

separated. They provide an improvement of the method with respect to the existing RFID corrosion sensors. An application of this method to corrosion monitoring in civil engineering structures will be investigated in future work. In particular, the aim will be to locate the steel sensitive element near rebars and the antenna at the concrete surface.

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References

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