Propagation channel modelling for near-ground and underground wireless sensor networks

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Context

The recent growth of Internet of Things (IoT) associated with the development of the new generation of wireless communication networks (beyond 5G, local, body, underground, etc.) offers the everywhere deployment of the connected devices. The pervasive deployment of the sensor networks is possible provided that a good energy efficiency of the network can be achieved. A key parameter to reach these objectives includes a more comprehensive knowledge on the physical layer of sensor networks. Consequently, a reliable prediction model for the electromagnetic wave propagation in the wireless sensor networks (WSN), especially in a complex scenario would be essential. Recently great attention has been drawn to sensor networks in which antennas are located close to the ground or are buried into it. In most applications the near-ground or underground sensor network is supposed to collect information for which the proximity to the interface or the immersion of the sensor into the lossy medium is required. Different application examples can be mentioned such as near-ground WSN for environmental monitoring or underground WSN for precision agriculture.

This PhD proposal aims to contribute to the radio channel modelling in near-ground and underground sensor networks where the close environment of antennas, near or inside the ground, must be carefully taken into account. Otherwise, the inaccuracy of the model leads to erroneous estimation of the path loss, thus to a suboptimal network design. The proposal is in line with the disciplinary project of ESYCOM laboratory and is presented in the wake of a previous PhD thesis.

PhD proposal

In literature, different measurement based studies can be found to treat the near-ground or underground wireless channel, for indoor/outdoor narrowband/wideband communication [1]-[4]. The shortcoming of these studies, in a similar way to other empirical approaches, is that their results are specific to the application parameters and they cannot easily be extended to other propagation scenarios. The lack of physical insight makes the understanding of the near-ground or underground propagation phenomenon more difficult. Physics-based approaches have the advantage of offering a better understanding of the phenomenon but their application in a real case scenario usually necessitates simplifying or idealising hypotheses. Common existing ray based techniques are not able to describe properly the physical phenomena behind the wave propagation since the ground scattering/diffraction is merely based on Fresnel reflection coefficients and do not take into account higher order wave components. In the domain of electromagnetics, the rigorous techniques of wave propagation modelling in the presence of or inside a layered lossy material (ground) has a very long and rich history. Many scientists have worked on Sommerfeld half-space problem. Although the mathematical and physical comprehension of the phenomena are guaranteed in this way, the analysis of the problem leading to the Green's functions formalism in its comprehensive representation makes the parameter manipulation for a link designer arduous [5]. Sophisticated physics-based yet easy-to-use propagation models for near-ground and underground sensor networks are scarce. However, we can mention a three-path model [6] for limited depth underground sensor network including the direct wave, the reflected wave and the "lateral wave" or a simplified underground channel model [7] based on the asymptotic development of Sommerfeld integral. Although these models include a third wave component, they do not expose the conditions under which the asymptotic developments have been made and they do not comment the domain of validity of the closed form expressions. Moreover, these studies do not cover the near-ground to near-ground scenarios nor the near-ground to underground wave propagation.

With respect to the state of the art, the objectives of this PhD thesis are:

- To provide simple, adapted and efficient propagation models based on a physical analysis for deploying near-ground or underground sensors.
- To demonstrate that the performances of an optimised near-interface propagation channel can outpass that of a conventional propagation scenario (without interface).

Work plan

This PhD work will be conducted in two parts: experimental and theoretical. The first aims to complete and verify in real conditions the accuracy of a theoretical model developed in a PhD work in ESYCOM Laboratory for sensors located near the ground. The second part concerns the development of a new theoretical model dedicated to communication between buried sensors close to air-ground interface.

1. Experimental part:

In [8]-[9], a theoretical channel model was developed for two elementary dipoles located near a lossy interface. This deterministic model shows that potentially, under certain conditions defined by the model parameters, near-ground propagation has a lower attenuation and is therefore more favourable than a conventional free-space propagation. From experimentation, the objective is to validate the theoretical propagation model presented in [8]-[9] in the context of near-ground sensor networks. This validation includes two axes:

- Propose a channel model based on a simple path loss (propagation in the presence of a lossy interface) combined with mask effects (local variability of the environment).
- Include antenna parameters in the proposed channel model to obtain a complete model dedicated to the design of near-ground sensor networks.

2. Theoretical part:

The second part of the thesis, to be conducted in parallel to the first part, concerns the extension of the theoretical model developed in [8]-[9] to buried sensors. This study is organised around two axes:

- Establish a theoretical model for wave propagation in a lossy medium between two buried sensors
- Establish a theoretical model for wave penetration into a lossy medium between an above-ground sensor and a buried one.

Applicant profile

This PhD offer is intended for the candidates having a Master's degree in « 3EA » or an equivalent degree in « Electrical engineering ». The following conditions are required:

- Solid knowledge in electromagnetics and applied mathematics
- Very high scientific rigour and strong theoretical abstraction
- Interest for experimentation
- Autonomy in computer programming

Contact

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The application file should include CV, statement of purpose, recommendation letters and all academic transcripts and may be addressed by email to Shermila Mostarshedi (Shermila.Mostarshedi@univ-eiffel.fr).

ESYCOM laboratory

The ESYCOM laboratory is within the field of communication systems, sensors and microsystems for the city, the environment and the person.
The topics of interest are more specifically:

- *antennas and propagation in complex media, photonic-microwaves components;*
- *microsystems for environmental analysis and pollution control, for health and the interface with living organisms;*
- *micro-devices for ambient mechanical, thermal or electromagnetic energy harvesting.*

References

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