# GROUND PENETRATING RADAR AND COOPERATIVE TARGET AS A TOOL TO ESTIMATE WATER CONTENT: NUMERICAL AND EXPERIMENTAL RESULTS

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## ABSTRACT

Ground Penetrating Radar (GPR) represents one of the most widely exploited diagnostics instrumentation in the fields of the water monitoring and management and recent application fields of the agricultural geophysics [1]. This is due to its easiness of use, flexibility, portability and a reasonable cost of the equipment and of the surveys [2].
In the framework of the water monitoring, GPR is a tool for an analysis at an intermediate scale between global vision, as the one ensured by the satellite observations, and punctual scale due to the use of the time domain reflectometry technique.

Many studies have been concerned with the use of GPR as tool to estimate the water content in the subsoil [3, 4]. The sensing phenomenon is based on the variation of the dielectric permittivity and conductivity (electromagnetic properties) ensured by changes of the water content in the soil; after this electromagnetic property are estimated by the GPR measurements. Accordingly, in an inverse problem, i.e., the estimation of the water content form GPR measurements, the problem can be formulated as a two-step one. The first step is related to the estimation of the electromagnetic properties starting from the GPR measurements; the second step is concerned with the passage, through analytical and empirical relationships, from electromagnetic properties to water content.

In this work, we focus on the first step, i.e., the determination of the electromagnetic properties from GPR data and we present the performance analysis by numerical simulation and experimenta in controlled conditions of a strategy based on the joint use of a cooperative targets and a microwave tomographic approach [5].

For this approach, we consider the problem of the determination the electromagnetic properties of the soil (dielectric permittivity and electrical conductivity) starting from the GPR measurements of the field backscattered by a buried cooperative target that has a cross-section small in terms of the probing wavelength [5]. Therefore, the electromagnetic properties of the soil are estimated as the ones that inserted in an inverse scattering model drive to the “reconstruction” closest to the known buried cooperative target (embedded in the soil on the purpose). Now, the problem of how quantifying the quality of the reconstruction arises, i.e. we have to identify a figure of merit that makes us able to characterize the “best” reconstruction.

In the case of a lossless or with low ohmic losses soil, it has been found that a criterion to evaluate the most focused image (at variance of the soil dielectric permittivity assumed in the Born model) is based on a sharpness measure Sharp(εb,σb) accounting for the maximum of the modulus of the reconstructed contrast function [5], where the soil dielectric permittivity and electrical conductivity are denoted by εb and σb, respectively. Therefore, in the lossless cases, a good criterion to retrieve the permittivity is to retain the model permittivity that allows to achieve the maximum value (vs. the model permittivity) of the maximum modulus of the contrast function (vs. the point in the investigation domain *D*) [6]. This approach has been tested numerically even in lossy cases, but only in situations where an accurate knowledge of the conductivity of the soil was available, the approach works satisfactorily.

Therefore, the need to define a new "figure of merit" arose in the realistic cases where the conductivity of the soil is known with some degree of uncertainty or not known and this can make unreliable the determination of the dielectric permittivity based on the previous criterion.. In this the, new figure of merit is proposed as "the criterion of the minimum support"; such a criterion is based on the determination of the area of the support of the retrieved contrast function [5]. In order to do this, we assume that the buried pipe is most focused when the area of the reconstructed spot is "minimum". The flow chart of the determination of the support is depicted in figure 1.

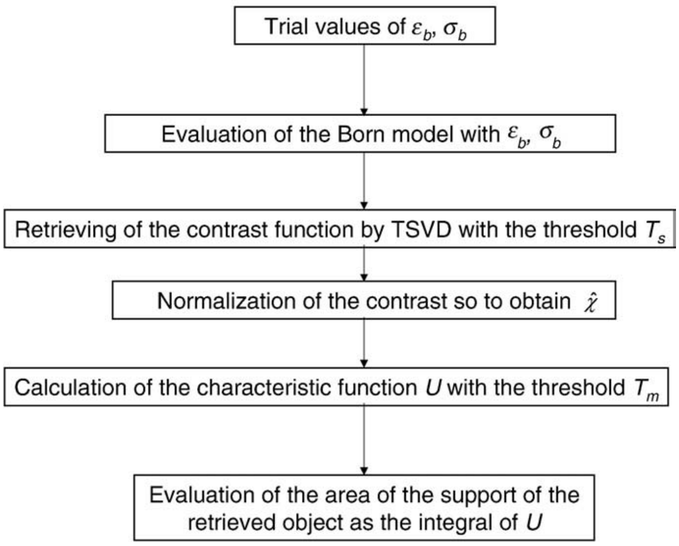


**Figure 1. Flow chart depicting the determination of the area of the support as the integral of the characteristic function**

The effectiveness of the two above defined criteria has been shown by resorting to a numerical analysis with simulated data.

The present work will present the performance analysis of the two criteria by cross-correlating the results of GPR with the estimations provided by TDR. Also, the results achieved by the microwave tomographic approach will be compared whit the usual estimation based on diffraction curves. The effect of the offset between the antennas and of the height of the observation line will be evaluated too vs. experimental laboratory data.

## REFERENCES

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