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Detection and Localization of Subsurface Two-Dimensional Metallic Objects

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Non-invasive identification of buried objects in the near-field of a receiver array is a subject of great interest, due to its application to the remote sensing of the earthś subsurface, to the detection of landmines, pipes, conduits, to the archaeological site characterization, and more. In this work, we present a Sub-Array Processing (SAP) approach for the detection and localization of subsurface perfectly-conducting circular cylinders.
We consider a plane wave illuminating the region of interest, which is assumed to be a homogeneous, unlossy medium of unknown permittivity containing one or more targets.
In a first step, we partition the receiver array so that the field scattered from the targets result to be locally plane at each sub-array. Then, we apply a Direction of Arrival (DOA) technique to obtain a set of angles for each locally plane wave, and triangulate these directions obtaining a collection of crossing crowding in the expected object locations [1].
We compare several DOA algorithms such as the traditional Bartlett and Capon Beamforming, the Pisarenko Harmonic Decomposition (PHD), the Minimum-Norm method, the Multiple Signal Classification (MUSIC) and the Estimation of Signal Parameters via Rotational Techinque (ESPRIT) [2].
In a second stage, we develop a statistical Poisson based model to manage the crossing pattern in order to extract the probable targetś centre position.
In particular, if the crossings are Poisson distributed, it is possible to feature two different distribution parameters [3]. These two parameters perform two density rate for the crossings, so that we can previously divide the crossing pattern in a certain number of equal-size windows and we can collect the windows of the crossing pattern with low rate parameters (that probably are background windows) and remove them. In this way we can consider only the high rate parameter windows (that most probably locate the target) and extract the center position of the object.
We also consider some other localization-connected aspects. For example how to obtain a likely estimation of the soil permittivity and of the cylinders radius.
Finally, when multiple objects are present, we refine our localization procedure by performing a Clustering Analysis of the crossing pattern. In particular, we apply the K-means algorithm to extract the coordinates of the objects centroids and the clusters extension.

References

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