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New approaches for three dimensional source location - examples from acoustic emission analysis

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The solution space of the three dimensional source location problem is hyperbolic, i.e. non-linear. The still most frequently used solving method deals with a linearization of the problem. This approach shows certain limitations concerning stability and accuracy of the solution. Therefore, several nonlinear location methods were developed which lead to more precise and more stable results even for sparse networks.
Another approach is closely related to an old theory. In 2005 it is 100 years ago that Albert Einstein developed the special relativity theory. The relativity theory requires the use of the space-time which is of hyperbolic geometry. The corresponding four dimensional space is the Minkowski space. Using these ideas of space-time a direct algebraic solution of the location problem is possible which was applied first in GPS navigation. This approach requires no linearization and no starting guess, even not for the over-determined case. The principle of the direct algebraic solvers is transferring the relative arrival times to pseudo-ranges with the help of the assumed velocity of the medium. After this step the mathematical tools of the Minkowski space can be applied. The direct solver approaches can be seen as a further development of the hyperbola method. The hyperbola method describes the point of intersection of hyperbolas while the direct algebraic solvers describe the intersection of hyperboloids of two sheets. Algebraic solution methods of the pseudo-range equations exist for the determined and also for the over-determined case.
In contrast to the well-known time-differences approach of acoustic signals, stating the system of non-linear equations in a GPS form is a new approach for acoustic spatial positioning. Both types of systems of non-linear observation equations are in-

terconnected through a simple difference equation. The pseudo-time or pseudo-range notation respectively turned out to be very universal for acoustic source location since it allows the utilization of the mentioned robust non-iterative GPS algorithms.

Both direct solver approaches are already successfully used in the field of electro technical engineering for the acoustic non-destructive diagnostic examination of large power transformers. To assess the insulation characteristic and quality of the transformers oil/paper-insulation system acoustic partial discharge measurements are carried out. Localizing these small insulation defects by means of radiated acoustic waves gives essential information for a safe operation to avoid unexpected failures of the transformer.

These direct solvers also succeed well for acoustic emission location in concrete. Concerning acoustic emission analysis concrete can be treated as an isotropic material. Sometimes larger additives or the reinforcement may disturb the homogeneity. Therefore, up to now only the case of sparse sensor networks was investigated and not the case of a heterogeneous velocity field. Due to geometry effects only the onsets of the P-waves are used for source location. The direct solver approaches deliver stable location results and are compared to locations gained with the Geiger-method.