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An Improved MUSIC Based Linear Array GPR CMP Velocity Estimation Technique

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Common Mid Point (CMP) is a standard technique in array Ground Penetrating Radar (GPR) processing, which provides precision estimation on subsurface layer information. The main idea of CMP velocity estimation technique is to pick out the best fitted arrival time-antenna offset hyperbolic curve on CMP profile. However, this process heavily relies on the signal amplitude, so that artifacts occur and the target will not focus well if system working bandwidth is narrow. This problem can be solved by using subspace techniques, for example, MUltiple SIgnal Classification (MUSIC). As the geometry arrangement of the array elements is known, received signal of all channels can be expressed by using a reference signal *s*(*t*) and exponential phase difference terms. Specifically, in CMP layer detection case, only layer depth and signal transmission velocity are unknown so that the variables range and angle in steering matrix *A* of 2D MUISC can be replaced by the layer depth *d* and the signal transmission velocity *v*, as shown in (1). ``

$$X(t) = s(t)A(d,v) + N \tag{1}$$

where $A(d,v)$ can be explicitly written as (2), assuming that the system has M antenna pairs.

$$A = [1, e^{j\omega \frac{2(\sqrt{d^2+\frac{x_2^2}{4}}-\sqrt{d^2+\frac{x_1^2}{4}})}{v}}{}^2 \ldots, e^{j\omega \frac{2(\sqrt{d^2+\frac{x_M^2}{4}}-\sqrt{d^2+\frac{x_1^2}{4}})}{v}}] \tag{2}$$

where x_i is the offset of the *i*th antenna pair. Rather than using the amplitude information of the received data, MUSIC takes the advantage of the orthogonality between the noise subspace and the steering matrix, which significantly enhances the target and improves signal to noise ratio. Generalized Eigen Value Decomposition (GEVD) is applied for MUSIC to handle more general cases, such as colored noise and undistinguishable clutter in the time domain, following

$$\mathrm{x}S_1\mathrm{x}^H = \mathrm{x}\lambda S_2\mathrm{x}^H = \mathrm{x}(S_2 + APA^H)\mathrm{x}^H \tag{3}$$

where S_1 is the covariance matrix of the array received data matrix and S_2 is the sum of term from the N related covariance matrix, λ is a diagonal generalized Eigen value matrix of matrix pencil $\{S_1,S_2\}$.The simulations are carried out by using 8 antenna pairs, transmitting and receiving signal in 2.0 to 2.4GHz SFCW mode. The subsurface layer is set to have a 1.8m depth and the signal transmission velocity is 0.134m/ns. The simulation results proves the feasibility and the accuracy of the proposed method, the target is much more focused and the artifacts are vastly reduced, as shown in Figure 1.

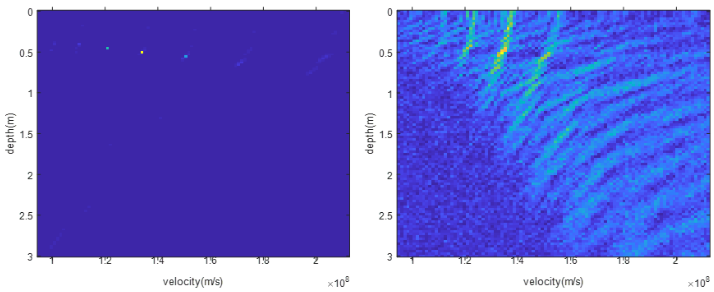

Figure 1. The simulation results of the proposed method and the conventional method