Fuzzy Pole Representation for SEM based Complex-Pole Scatterer Signature

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The singularity expansion method (SEM) based representation of scatterer response in terms of complex poles (C. E. Baum, *IEEE Ant. & Prop. Society Symp.* **11**, 459-462, 1973) has found widespread application in target identification, ground penetration radar, and tumor detection. However, achievable benefits for these applications are limited due to measurement noise. Noise creates spurious poles with corresponding residues. Moreover, noise makes it difficult to determine the actual number of complex poles needed to characterize the time-domain signature. A close observation of the collection of estimated poles from various samples of noisy time-domain data indicates a formation of clusters around the actual poles. In this paper, a modified fuzzy clustering approach is proposed as a solution to overcome the effect of noise, which has not been previously reported.

The original contribution is the demonstration that estimated fuzzy poles offer a close match to the actual poles determined from the simulated data for a thin wire. The time-domain response is analyzed using the Matrix Pencil Method and the fuzzy poles are computed using a modified version of the Unsupervised Optimal Fuzzy Clustering (UOFC) algorithm (I. Gath and A. B. Geva, *IEEE Trans. Pattern Anal. & Machine Intelligence*, **11**, 773-780, 1989). UOFC is a blind partitioning algorithm that does not require any a-priori information on the number of clusters. The membership values are indicative of the cluster to which the estimate pole belongs with values close to unity corresponding to strong membership. The UOFC algorithm is modified by introducing a weighting of the residue values. The estimated fuzzy poles using the modified UOFC algorithm match closely to the actual poles.

The estimation of the actual poles using the fuzzy clustering approach is demonstrated for the simulated response of a thin wire. Simulated results indicate that fuzzy characterization has promising application in target identification and discrimination, which uses noisy time-domain ultra-wideband radar response. Advances in identification of clusters using fuzzy algorithms offers an alternative approach to estimating poles about the true complex poles within the cluster in presence of noise.