3-D characterization of buildings in a dense urban environment using L-band POL-inSAR data with irregular baselines

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Several High-Resolution (HR) spectral analysis techniques have been applied to the estimation of building height using multibaseline interferometric SAR (MB-InSAR) data, in order to investigate problems linked to the complexity of scattering patterns over dense urban areas. A recent study by Sauer et al.[1] proposed to apply polarimetric versions of spectral estimation methods (Capon, MUSIC, Maximum Likelihood (ML)) to the case of airborne polarimetric MB-InSAR data sets acquired at L-band. Results showed that using polarimetric data could improve building height estimation, both in terms of discrimination of mixed scatterer responses (layover, vegetation ...) and determination of physical characteristics of the observed media. Despite undeniable performance improvements such an approach may meet some limitations:

— As shown by Ferro-Famil and Pottier[2], scatterers in urban areas may have very different statistical properties that are not optimally handled by the methods proposed by Sauer et al. and may involve estimation errors and instability.

— Processing InSAR data acquired from irregularly distributed baselines can cause ambiguous responses and sidelobe effects that may lead to erroneous interpretations and estimations.

In this paper, we propose to overcome these limitations using subspace fitting methods and unambiguous baseline analysis.

We first show that over urban areas, scattered signals can be categorized in two types defined by the Conditional and Unconditional Model assumptions (CM and UM)[3], which correspond to coherent (e.g. point-like scatterers) or speckle affected (e.g. surfaces or vegetation), responses respectively. Under the CM assumption, the source signal is deterministic and its parameters are estimated using a nonlinear least square optimization. A source signal following the UM assumption is stochastic, and its parameters are estimated from its covariance information. The ML estimation of building height leads to different UM and CM solutions, the latter being inconsistent. In order to overcome these problems, building height is estimated using Weighted Subspace Fitting (WSF)[4][5], which adapts to the nature of the source signal while remaining statistically efficient, even for coherent signals. A height and model order (number of relevant sources) fully polarimetric WSF estimator is developed, which allows to retrieve optimal scattering mechanism and polarimetric reflectivity.

As mentioned earlier, irregular baseline sampling generally leads to ambiguous estimates and spurious sidelobes. The problem of estimating spectral lines from irregularly sampled spatial data is handled by minimizing a composite criterion[6] which is formulated as a penalized weighted subspace fitting function. Among all the solutions of this spectral estimator, the sparsest one is used to find more precise and unambiguous source locations. Since the amplitudes might be underestimated by this spectral estimator, nonlinear least square can be used to estimate accurate reflectivities of sources, after obtaining the source heights.

The effectiveness of the proposed polarimetric WSF estimator and the sparse method for irregularly sampled data is demonstrated using multibaseline PolInSAR data acquired by DLR's E-SAR system at L-band over an urban area of Dresden.

REFERENCES

[1]S. Sauer, L. Ferro-Famil, A. Reigber and E. Pottier, ''3D Visualisation and Physical Feature Extraction of Urban Areas using Multibaseline POL-InSAR Data at L-Band''*, IEEE Urban Remote Sensing Joint Event 2007,* pp. 1-5, April 2007 .

[2] L. Ferro-Famil, E. Pottier, ''Urban area remote sensing from L-band PolSAR data using Time-Frequency techniques'', *IEEE Urban Remote Sensing Joint Event 2007*, pp. 1-6, April 2007.

[3]P. Stoica and A. Nehorai, "Performance study of conditional and unconditional direction-of-arrival estimation," *IEEE Trans. Acoust., Speech, Signal Processing*, Vol. ASSP-38, pp. 1783-1795, Oct. 1990.

[4]M. Viberg, B. Ottersten, ''Sensor array processing based on subspace fitting'', *IEEE Trans. Signal processing*, Vol. 39, Issue.5, pp. 1110-1121, May 1991.

[5]A. Swindlehurst, M. Viberg, "Subspace Fitting with Diversely Polarized Antenna Arrays", *IEEE trans. Antennas and propagation,* Vol. 41, No. 12, pp. 1687-1694, Dec.1993.

[6]Donoho, D.L., Elad, M. , Temlyakov, V.N., ''Stable recovery of sparse overcomplete representations in the presence of noise'', *IEEE trans. Information Theory,* Vol. 52, pp. 6- 18, Jan. 2006.