MULTI-BASELINE ALONG TRACK SAR INTERFEROMETRIC SYSTEMS FOR GROUND MOVING TARGET INDICATION

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Ground moving target indication (GMTI) is a very difficult problem, due to the difficulty of separating the signal returned from a moving target from the stationary background (clutter).

Several methods, based on very different approaches, have been proposed in literature. Examples of this include displaced phase centre antennas (DPCA systems) and space-time adaptive processing (STAP). DPCA synthesizes a static antenna system allowing cancellation of static returns on a pulse-to-pulse basis similar to that used in ground based MTI system [1]. Other techniques for enhancing the target Doppler signature against the competing ground clutter returns use STAP processing [2], which is optimum if uses more than two channels but is computationally very demanding [1].

Along Track Interferometric Synthetic Aperture Radar (AT- InSAR) systems can be used for GMTI by exploiting two images obtained on the same scene by two SAR antennas separated along the flight direction by a distance called *baseline* [3-6].

The information about the target radial velocity is estimated from the interferometric phase obtained by beating the two SAR images. The phase is measured in the interval $(-\pi,\pi]$, so that a *Phase Unwrapping* (PhU) operation is required to retrieve the target radial velocity [7,8].

In this paper an automatic detection scheme with constant false-alarm rates (CFARs) based on the Generalized Likelihood Ratio Test (GLRT) and on Gaussian statistics for the target response, and for the case of multi-baseline systems is proposed.

We use a multi-baseline system, obtained by using more than two antennas, since different phase measurements helps to find a reliable solution for the velocity estimation and to solve ambiguity problems [7]. We exploit the multi-baseline acquisitions also for the detection problem since exploiting more than two images of the same scene considerably improve the moving target indication performance.

We assume a Gaussian model for the target response, for the stationary clutter and for the additive thermal noise in the receiver. The N-baselines acquisitions are related to the same area and separated by a slight time difference such that they can be considered highly correlated, producing an N-dimensional Gaussian vector characterized by a different covariance matrix in the two hypotheses (absence and presence of the moving target)

In order to detect the target we have extended to the N-dimensional case the method proposed in [6] exploiting a GLRT. The GLRT test requires a preliminary step for the Maximum Likelihood (ML) estimation of the target radial velocity and of the signal to clutter power ratio (SCR). Then, we compute the probability density function (pdf) of the log-likelihood ratio in closed form, both in the hypothesis of presence of a moving target and in absence of a moving of target. The pdf closed form has been found by considering that the log-likelihood ratio can be expressed by a Hermitian quadratic form obtained from N-dimensional Gaussian vectors. In Fig 1 the analytical and the empirical probability distribution of the quadratic form are reported in the 3-dimensional case, in this case two interferograms can be exploited to estimate the velocity and to detect the target.

Once obtained the pdf closed form, the log-likelihood ratio can be evaluated in correspondence of the estimated velocity and SCR values, and the optimal threshold, with which the log-likelihood ratio has to be compared to obtain a given probability of false alarm (P_{FA}), can be easily evaluated. The corresponding values of the probability of detection (P_D) are then evaluated. The moving object detection capability will depend essentially on the target radial velocity, on SCR and on CNR (the clutter to noise ratio, defined as the ratio between the power received from the stationary clutter and the thermal noise power) and on clutter coherence, that in the case of Along Track systems can be considered equal to one.

The detection performance evaluation has been performed using the TerraSAR-X parameters. Numerical results based on simulated data show the effectiveness of the proposed approach and the improvements with respect to the case of a single interferogram [6]. In Fig 2 is shown the Receiver Operating Characteristics (ROC) obtained for a radial velocity value v_r=82 km/h, CNR=10 dB, SCR=10 dB in two cases, a single interferogram (solid line) and two interferogram (dashed line). We observe the significant improvement in terms of probability of detection that can be achieved for a fixed P_{FA} when are available two interferograms instead of only one.

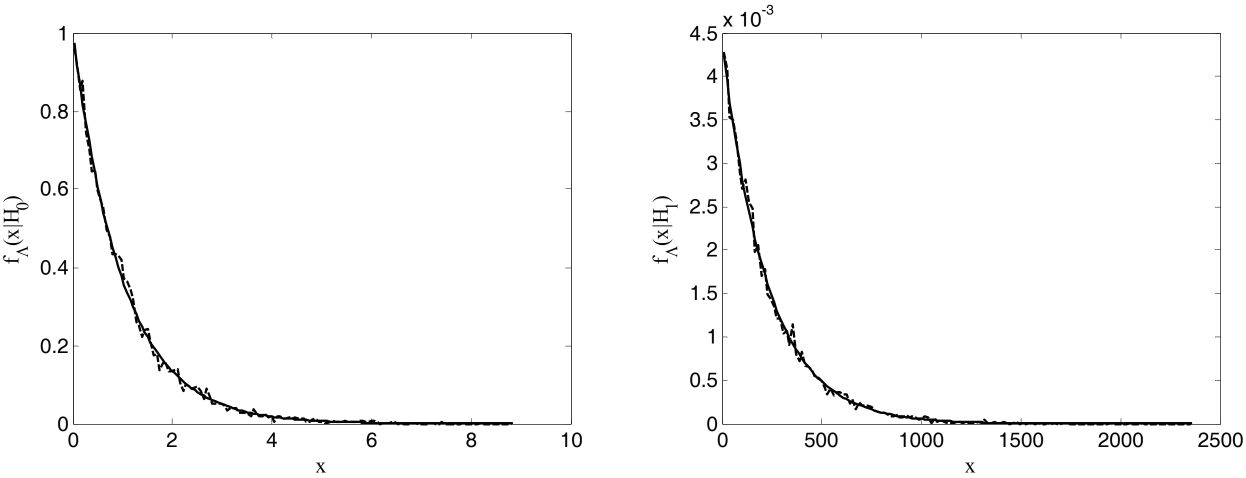

Fig.1: Empirical (dashed line) and analytical (solid line) pdfs of the quadratic form in the two hypothesis H_0 (a) and H_1 (b), for 2 interferograms and for v_r=82 km/h, CNR=10 dB and SCR=10 dB.

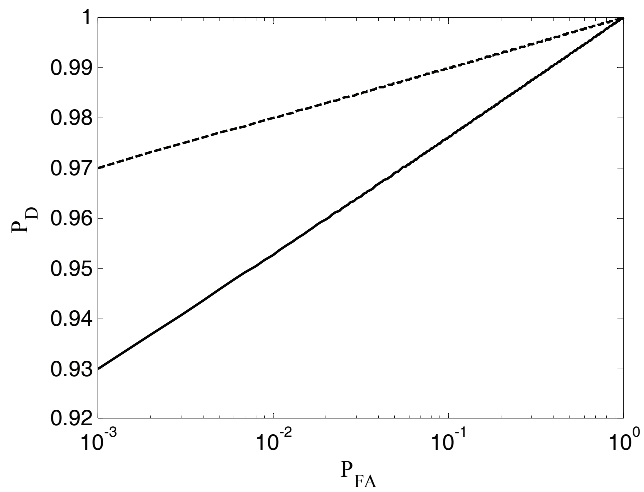

Fig. 2: ROC (P_{FA} in log scale) for CNR=10 dB and SCR=10 dB, for v_r=82 km/h for one interferogram (solid line), compared with the one obtained with two inteferograms (dashed line).

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