Optimal sensor placement for Multi-bistatic ISAR imaging

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***Abstract*— Inverse Synthetic Aperture Radar (ISAR) images are typically used for target recognition and identification purposes. The target projection on the ISAR image plane depends on the target's own motions and on the relative position of target and radar. Since targets of interest are often non-cooperative, the first condition is not under the radar's control. Nevertheless, the relative radar-target position can be somehow controlled or predicted in some cases. Moreover, the use of multiple receivers enhances the likelihood that a desired radar-target position occurs during radar measurements. In this paper, the theoretical aspects of optimal sensor positioning for obtaining desired ISAR image projections are detailed. A mathematical tool will be presented that is able to predict the optimal sensor positions for maximising the probability of obtaining a desired ISAR image. Real data will be used that demonstrate the effectiveness of the proposed tool.**

I. Problem Statement

One of the major problems in ISAR imaging is that the image formed at the end of the process is a 2D projection of the true target reflectivity onto the ISAR Image Projection Plane (IPP) [1], [2]. The orientation of this plane depends on the sensor position relative to the target and on the target motion, which, in the case of non-cooperative targets, is not under the radar operator's control. The result of this is that the target projection seen in the ISAR image becomes arbitrary, which makes the interpretation of the ISAR image, and consequently the recognition of the target, a much more difficult task. In addition to this problem, the ISAR image cross-range resolution is unknown a priori because it also depends on the target's own motion. To circumvent these issues, it is often assumed that data has to be collected over a sufficiently long duration to obtain at least one suitable frame with a desirable resolution and IPP. A costly solution to this problem is that of having several ISAR systems in a spatially diverse configuration, which are then able to look at the target from different points of view.

In this paper a novel approach is discussed that aims at maximising the probability of obtaining one or more ISAR images with desired IPPs. The idea is that of combining the use of a multi-bistatic configuration with optimal sensor placement [3]. A multi-bistatic configuration can be seen as a Single Input Multiple Output (SIMO) configuration, where a transmitter is considered together with a number of receivers. The problem of receiver optimal placement, given the positions of the transmitter and the target, is addressed by maximising the probability that a desired IPP is obtained subject to a constraint set on the bistatic ISAR image resolution.

The Bistatically Equivalent Monostatic (BEM) approach is followed in order to derive the optimisation problem in a simpler monostatic manner [4]. Side and composite front/side views will be considered in this paper as desired IPPs and their probabilities will be maximised to obtain the optimal distribution of the receivers in the 3D space. Real target motion data will be used to demonstrate the concept.

II. Bistatic ISAR Signal Model

The geometry of a multi-bistatic configuration is considered, where a transmitter and N receivers are not co-located. The signal received by the j-th receiver can be written in a time-frequency format as follows [4]:

$$S_R^{(j)}(f,t) = W(f,t) \int \zeta(\mathbf{x}) \exp\left[j\varphi_j(\mathbf{x},f,t)\right] d\mathbf{x} \quad (1)$$