Strategies for Sub-optimal Air to Air STAP in Forward Looking Configuration

Diego Cristallini[1], Wolfram Bürger[2]

Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR
Neuenahrer Str. 20, D-53343 Wachtberg, Germany

[1]diego.cristallini@fhr.fraunhofer.de
[2]wolfram.buerger@fhr.fraunhofer.de

***Abstract*— This paper deals with the selection of adequate sub-optimal strategies for air to air STAP in a forward looking configuration. The particular scenario is characterized by: (i) need of real-time operability; (ii) strong range dependency of the clutter statistics. To overcome these two aspects, a reduction of the overall number of degrees of freedom (DOFs) has to be performed, thus sub-optimal STAP approaches must be used. In addition, the range dependency of the clutter limits the overall number of available secondary data for clutter covariance matrix estimation. Three strategies for secondary data collection are presented and the corresponding performances are compared for a sample scenario.**

I. Introduction

Space-time adaptive processing (STAP) for airborne radar has been extensively covered in the open literature, [1, 2]. However, most publications have focused on the use of STAP for ground moving target indication (GMTI) using a side looking antenna configuration and a low pulse repetition frequency (LPRF) mode. By contrast, the use of STAP in air to air operations using a forward looking antenna configuration has not been analysed much in the literature, although it offers significant performance improvement [3]. Using STAP, tangential or rear aspect air targets, which are detected and tracked using a medium pulse repetition frequency (MPRF) mode, become visible even if they were previously hidden in mainbeam or sidelobe clutter.

As in the case of GMTI/STAP, it is not feasible to use the optimum space-time adaptive processor in air to air modes. The main problems are

(i) the computational load imposed by the optimum processor, which precludes its real-time operation, and
(ii) the range dependence of the clutter statistics, which makes it impossible to collect enough statistically similar secondary data for the estimation of the adaptive weights. This is even more of an issue in air to air modes, where the clutter is range ambiguous.

Sub-optimal STAP approaches are mandatory to overcome these issues. This paper deals with the identification of adequate sub-optimal STAP techniques as well as with corresponding strategies for secondary data collection.

II. Clutter In Forward Looking Radar

In airborne radar, the echoes of stationary scatterers are Doppler shifted due to the platform motion. In particular, this Doppler shift is proportional to the cosine of the angle between the flight direction and the direction of the scatterer, and is range dependent unless the antenna is aligned with the direction of flight, i.e. a side looking linear array. Even in completely homogeneous terrain, the clutter in forward looking radar will therefore be non-stationary along range.

In air to air operations, the target velocities of interest and therefore also the PRF employed are much higher than in air to ground modes. For this reason, clutter in air to air modes is always range ambiguous. Most air targets will be detected and tracked at ranges far greater than the unambiguous range determined by the PRF. They will therefore have to compete against both the mainbeam clutter and the sidelobe clutter from all ambiguous range gates. In view of the radar equation, the sidelobe clutter power from the ambiguous range gate closest to the radar may exceed the mainbeam clutter power contributed by the range gate containing the actual target. The resulting poor signal-to-clutter-plus-noise ratio (SCNR) makes endo-clutter target detection in MPRF modes much more difficult than in range unambiguous LPRF modes.

Fig. 1 shows the clutter power in the sum beam of a forward looking array radar system operating in an MPRF mode, plotted over Doppler frequency and range. The aircraft was assumed to be in level flight above flat ground. The range ambiguities manifest themselves in the pronounced mainbeam clutter ridge. The range dependency of the clutter spectrum is mainly due to sidelobe clutter, see for instance the structures present at about 14 and 20 km.

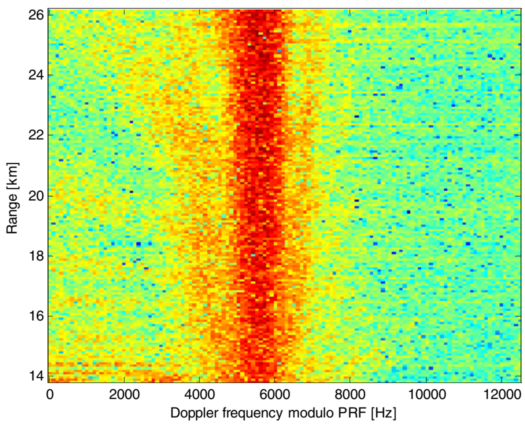

Fig. 1 Clutter power in the sum beam of a forward looking active electronically scanned array (AESA) radar operating in MPRF mode [dB]