Exploiting dual-polarization technique in weather radar for civil aircrafts to mitigate risk in adverse conditions

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Trajectory of civil aircrafts is typically optimized off-board to optimize fuel consumption, using also information available from weather services. Changes to the set route are decided by the pilot based on METAR and NOTAM updates and unexpected adverse weather conditions detected by the weather radar installed on the nose of the aircraft [1]. Typically, weather radars of most civil aircrafts are single-polarization X-band systems (only larger airplanes use C-band) with 3° beam-width flat antenna, following the specifications set by the ARINC 708A standard. Notoriously, attenuation due to propagation through a precipitation filled medium is not negligible at X-band and in the presence of cluster of convective cells, the nearer cells masks or weakens returns from farther cells, ultimately determining a wrong input to the pilot's decision on optimal trajectory. Unfortunately, attenuation correction techniques applicable to single polarization radar are notoriously unreliable and strongly affected by radar calibration bias. Conversely, dual polarization technologies in ground based weather radar have demonstrated the capability of mitigating X-band attenuation based on differential phase shift measurements [2] and therefore could be successfully exploited for civil aviation weather radars. Current systems show to the pilot precipitation returns according to a few levels of reflectivity (the correspondence between colors and levels of reflectivity is not shown) and, within a shorter range, also information on turbulence detected from radar Doppler spectrum width. Meteorological interpretation of such images is largely left to the pilot's experience. Dual polarization radar provides more information arising from the sensitivity their measurements to microphysical properties of particles exploited in hydrometeor classification products [3]. On the other hand, dealing with more information yields increased workload for pilot and therefore, to keep simple and effective the information shown to the pilot, an automated software to process dual-polarization measurements along with trajectory information to support the pilot in decision making is essential. The European Union, through the Clean Sky framework funded several projects to improve airborne weather radars and to optimally use them to optimize flight route. The project KLEAN aimed at using output of the Selex ES Weather Radar Post-Processor software (WRPP) inside an EFB (Electronic Flight Bag) to produce weather classification maps and related binary risk maps as the final radar product to be shown to the pilots or to be used by a trajectory optimizer.

This paper focuses on the WRPP results in terms of weather classification and binary risk maps assuming reconstructed true flight and weather scenarios and simulated outputs of a dual polarization X band avionic radar. To test EFB algorithms, a case characterized by a supercell thunderstorm where strong hail and rain are present along with likely strong turbulence with gust fronts [4]. Two altitude flight levels are simulated, at 9000 and 6000 meters assuming true flight routes on the European area. A Support Vector Machine (SVM) classifier has been implemented [5] [6] that uses as inputs the polarimetric observables, namely Z_H, Z_{dr}, K_{dp}, $|\rho_{HV}|$, and the geolocation information obtainable from the Flight Management System of the aircraft.

All tests are performed with the C-source code for EFB running on a Quad Core PC Intel-i7@3,40GHz. Classification takes a few tenths of a second to perform classification of a radar sweep. Future actions to increase the technical readiness level for aircraft operations includes validation of EFB software with real X-band dual-polarization data collected by an aircraft equipped with a prototypal looking-ahead dual polarization radar as part of the ongoing X-Wald project ("Avionic X-band Weather signal modelling and processing validation through real data acquisition and analysis scenario") [7].

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