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Optimal Combination Of External Calibration Techniques For C-Band Polarimetric Weather Radar Performance Monitoring

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Calibration is a key element to control the impact of the radar system error on the weather radar measurements. The miscalibration due to the radar system affects the quantitative estimation of the precipitation intensity and hydrometeors classification. The aim of conventional calibration techniques is to estimate the copolar and differential reflectivity calibration measurement by obtaining an uncertainty not exceeding 1 dB and 0.1 dB, respectively (Gorgucci et al., 1999). The external calibration technique usually considered to quantify the bias of the whole radar system uses a suspended metal ball with a balloon as a reference target for the radar beam. On the other hand, the internal calibration analysis can provide a partial (i.e. it excludes the radome effects), but accurate measure of the contribution of each radar module in terms of supplied power, losses and noise, with the aid of synthetic pulse generators and network analysers. Recently, the renewed attention on the calibration topic is devoted to obtain a consolidated approach to monitor all system parameters in a continuous manner and to underline that the use of a single method is neither sufficient nor accurate for this purpose (Ice et al., 2014). A single calibration method does not allow having an accurate real time monitoring, both because each technique need to a particular weather condition for its application (precipitation, clear air or presence of sun interference) and because the comparison of different values may be useful to extract more information (e.g.: system calibration error, receiver calibration error). Therefore the periodic nature of the system check based on a single technique is not and optimal choice to obtain a real-time weather radar monitoring.

In this study we present a new approach to combine different weather radar calibration procedures in an optimal way to obtain a reliable monitoring of the system in real-time. The use of fuzzy logic to synthesize the calibration information is applied on the different techniques and the output is a diagnostic quality index or decision value. This index can be useful to establish where (e.g. in the RX or TX section) and when (in between two maintenance operations) a technical intervention on the radar system is necessary. The used approach puts together more than one technique with different external references (e.g., precipitation, ice, sun and ground-clutter) in order to perform an estimation of the system miscalibration and then to check the status of the system without stopping its workability. One of the elements considered as external calibration reference is the ground clutter. For this reason, a new ground-clutter spatial-analysis has been developed to select a robust clutter reference in term of spatial variability and its temporal statistics. The output of the new ground-clutter spatial-analysis is then used to estimate the relative radar calibration. The information acquired through our combined approach are extremely important for the real time diagnosis of the radar system state.

A brief description of the single techniques applied is reported for the reader convenience. An absolute calibration, based on polarimetric features in the precipitation medium is used to obtain a system calibration value of the copolar reflectivity (Gorgucci et al. ,1999). The zenith observation of the medium in light rain under the melting layer and in ice above the freezing level is also applied to carry out the calibration value of the differential reflectivity. A monitoring radar receiver using as a reference in the analysis the solar flux acquired by the Dominion Radio Astrophysical Observatory (DRAO) at 10.7 cm wavelength and solar interference measured by the radar in clear air is applied to carry out a receiver calibration error value of the copolar and differential reflectivity (Holleman et al., 2010). Few works have attempted to track the features of the ground clutter both temporally and spatially with the aim of using it for calibration purpose. In this study, a new calibration monitoring is performed through the study of the ground-clutter echoes, as well. The methodology introduces a Bayesian classification scheme to segment each radar resolution volume into meteorological and ground-clutter echoes. After the data segmentation we apply a ground-clutter spatial analysis to select a robust clutter reference (in terms of spatial variability of its statistics) based on a region merging algorithm. The temporal series of the weather radar products have been analysed using the percentile and mean value of the robust clutter reference in order to estimate the relative calibration and its uncertainty.

The steps of the fuzzy logic approach are briefly introduced. The fuzzification state is a mapping of a calibration error bias defined into the impact of the error on the parameter estimation limited within a confidence interval. The inference rules state is divided into two parts to obtain a quantitative error index for the system and the receiver part. The set of the quality index of calibration correspond to a quality matrix is the inference rules output calculate with fixed weights and differential weights as a reciprocal norm-2 of the linguistic variable. The defuzzification state wants to underline the worst case of the calibration monitoring by calculating the minimum of the quality matrix for both the observed variable and TX-RX. At the end we have a fusion of different techniques and an index expresses the impact of the calibration error bias on the rain rate estimation. The idea of introducing a general FL methodology is to progress this approach to obtain a general global index that includes a more complete characterization of the calibration errors exploiting the available polarization variables (e.g. cross-correlation coefficient and differential propagation phase shift).

This work will show the potentials of the developed quantitative support tool, based on all available calibration techniques in order to have a complete and update characterization of the radar system state. A pre-operational and real-time monitoring of the calibration error is tested on a C-band radar site in Rome (Italy) showing the good agreement of all the techniques applied. This result is encouraging to deepen more the analysis and fostering the set up of hoc field campaigns to validate our calibration results on longer periods.