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Foreword

THE OPERATIONAL SIGNIFICANCE OF EIGENOR'S TRIPLE-PRT PROCESSING METHODOLOGY

The Finnish Meteorological Institute (FMI) has long experience of providing services based on weather radar observations. Several thousand individual data and image products are disseminated to public and private users every hour. FMI provides Finland's national weather service and all branches of this organization are heavy users of weather radar products. Due to user requirements and the fact that FMI has recently opened radar data for free use, we set high standards for the quality of radar data and products. FMI is therefore continually searching for and developing advanced technologies and methodologies that will enable us to provide new and improved weather radar products and applications.

As part of a nationally-funded research project, experienced weather radar professionals at FMI have conducted careful comparisons of radar image products created with the Vaisala RVP900 signal processor from successive equal scans using (a) classical processing by applying Vaisala's IRIS software and (b) Eigenor's triple-PRT processing. The system used in these tests was the polarimetric C-band radar located at the University of Helsinki, Division of Atmospheric Sciences. Cases employed in the comparison process cover both winter and summer seasons and many types of phenomena such as rainfall and snowfall (both wet and dry), widespread frontal precipitation and severe convection, graupel and hail, sea and ground clutter (in regular and anomalous propagation) as well as clear air echoes from insects and birds. A summary of the main conclusions follows.

In general terms, the classical quantities of equivalent radar reflectivity factor Z_e (with and without clutter filtering, denoted as dBZ and dBT in IRIS systems, respectively), Doppler velocity (v), and spectrum width (σ) as well as the polarimetric measurables of differential reflectivity factor (Z_dr), copolar correlation coefficient (ρ_co), and differential phase shift (Ψ_dp) exhibit patterns comparable with the well-established IRIS output. No significant anomalies could be found in cases processed using triple-PRT.

When handling some issues, triple-PRT processing provides better performance than classical single-PRT or dual-PRF processing. Adaptive clutter filtering in triple-PRT definitely improves the quality of reflectivity measurements. Flagging of very intensive ground clutter targets is a useful tool for diagnosing bins with "no hope of obtaining weather information". A significant improvement in the triple-PRT reflectivity field is the complete or almost-complete absence of the so-called Doppler snake, a local banded reflectivity minimum along the curve where the Doppler velocity is close to zero. This artifact regularly introduces bad local quality (underestimation or even a total loss of signal) in radar-based quantitative precipitation estimation (QPE), especially in cases of widespread precipitation when the wind direction remains constant during longer periods of precipitation accumulation. Some FMI systems also suffer from bad quality of Z_e in classical dual-PRF measurements, presumably due to an unknown bug in the system. This error vanishes when triple-PRT is used.

A useful benefit of triple-PRT signal processing is clearly the widely-extended unambiguous retrieval of Doppler wind velocities that the method provides for winds up to ±50 m/s or more. Folding is completely avoided even in cases when the echo pattern is fragmental. Unfortunately, the measurement of tornado cases during our research project was not possible because they are a rare occurrence in Finland, but the wide unambiguous velocity range helps in the proper diagnosis of, for example, low-level frontal jets. Triple-PRT wind processing also provides additional useful wind information as a diagnostic tool for characterizing how much the spectrum deviates from the ideal Gaussian spectrum, a quality metric calculated with wind products for thresholding purposes. We have observed that in some cases where a strong signal is linked with vertical wind shear, this metric can be low, suggesting that there is potential for estimating the intensity of turbulence.

To guarantee the high availability of services, radar must be able to complete 98–99% of scheduled measurements on a yearly basis, and therefore all novel solutions implemented at FMI must of course be fully tested over the whole range of extreme weather and seasonal variations. To follow up on the detailed documentation and promising case studies provided in this book and elsewhere, the logical next step — and one that I recommend — is the implementation of triple-PRT processing as part of an operational/research system over an extended period.

This book provides a very precise and useful presentation of Eigenor's triple-PRT methodology and is therefore a recommended reference for organizations and individuals who wish to understand and use it.

Jarmo Koistinen
Senior Research Scientist
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Preface

This report reviews the triple-PRT Doppler weather radar signal processing algorithm designed and employed by Eigenor Corporation. Our triple-PRT setup is an example of a non-uniform pulsing scheme in which patterns consisting of three pulses are transmitted consecutively. The use of triple-PRT pulsing makes it possible to extend the unambiguous Doppler velocity range significantly and cover velocities encountered in typical weather phenomena, including velocities higher than 50 m/s, without imposing additional restrictions on the radar's operating range. Contrary to popular belief that the development of proper ground clutter removal algorithms for non-uniform sampling methods is not possible, we demonstrate a ground clutter removal system that offers performance superior to that of standard schemes. This document focuses primarily on the performance of ground clutter filtering with triple-PRT processing. The techniques reviewed in the report have been tested with triple-PRT radar measurements collected in the spring and summer of 2012 at the University of Helsinki. The radar used was a standard dual-polarization C-band weather radar manufactured by Vaisala and located on the university campus. Triple-PRT, single-PRT and dual-PRF measurements were taken in sequence, and the single-PRT and dual-PRF measurements were processed using the standard algorithms supplied with the Vaisala RVP900.

The document begins with a discussion of the basic concepts which are vital for understanding the methods employed, including the fundamentals of Doppler radars and ground clutter signals. In Chapter 2, several commonly-used ground clutter removal algorithms are reviewed and compared with the triple-PRT method developed by Eigenor Corporation. Chapter 3 provides an explanation of triple-PRT processing, and Chapter 4 deals specifically with the high-pass filter used in our tailored method of ground clutter removal. Chapter 5 describes how meteorological quantities of primary interest such as reflectivity, velocity and the width of the velocity distribution are estimated from measured signals. An important feature of an advanced clutter-removal algorithm is that it should only be applied when necessary, and this topic is handled in Chapter 6. The algorithms are tested against both simulated and measured data in Chapters 7 and 8, respectively. Conclusions and a discussion of our findings are in Chapter 9.