

Analysis of dual-polarization antenna performance and its effect on QPE

Dmitri Moisseev¹, Reino Keranen², Pekka Puhakka², Juha Salmivaara², Matti Leskinen¹

¹ University of Helsinki, Finland, *firstname.lastname@helsinki.fi*

² Vaisala, Finland, *firstname.lastname@vaisala.fi*

1. Introduction

Antenna plays a major role in the quality of dual-polarization radar precipitation measurements (Chandrasekar and Keeler, (1993); Moisseev et al. (2000), Mudukutore et al. (1995)). In this study, antenna patterns of two C-band weather radars were measured and analyzed antenna. Based on the measurements, assessment of dual-polarization performances of the antenna systems was carried out. Using the radar systems, as examples, a detailed analysis on how antenna influences dual-polarization radar observations of precipitation is carried out.

For this study the facilities at University of Helsinki Kumpula and Vaisala Kerava radar sites were used. Both sites are located in the Greater Helsinki region, at a distance of 22 km from each other. Due to the favorable location of the two sites, antenna pattern for one of the radars can be measured using the antenna of the other system. In this setup, continuous wave signal was injected into the feed of one of the radars while the other radar was carrying out box scans. In addition, independent sun measurements have been carried, to assess applicability of sun observations for antenna quality tests.

Finally, quality of the observed polarimetric variables in light rainfall was studied. Not surprisingly, it was found that the antenna beam patterns are the limiting factors in quality of the polarimetric variables, namely differential reflectivity, differential phase and co-polar correlation coefficient. It was also observed that sun scans provide a very sensitive test of the mismatch of the antenna patterns at two polarizations.

2. Measurement setup



Figure 1 Map of Helsinki region (Kumpula-Kerava Map, 2010). Circles denote locations of University of Helsinki Kumpula and Vaisala Kerava Radars.

The map of the measurement setup is shown in Figure 1. Kumpula radar is located on the roof of the Department of Physics building 59 m above the mean sea level. The Kerava radar is located on top of an old water tower, 95 m above the mean sea level.

The antenna measurements were carried out in February – March 2009. During the measurements, continuous wave signal from a signal generator was injected into the feed of one of the radars while the other radar was carrying out box scans. The procedure was repeated for both radars, where each radar acted as a signal source.

3. Antenna measurement results

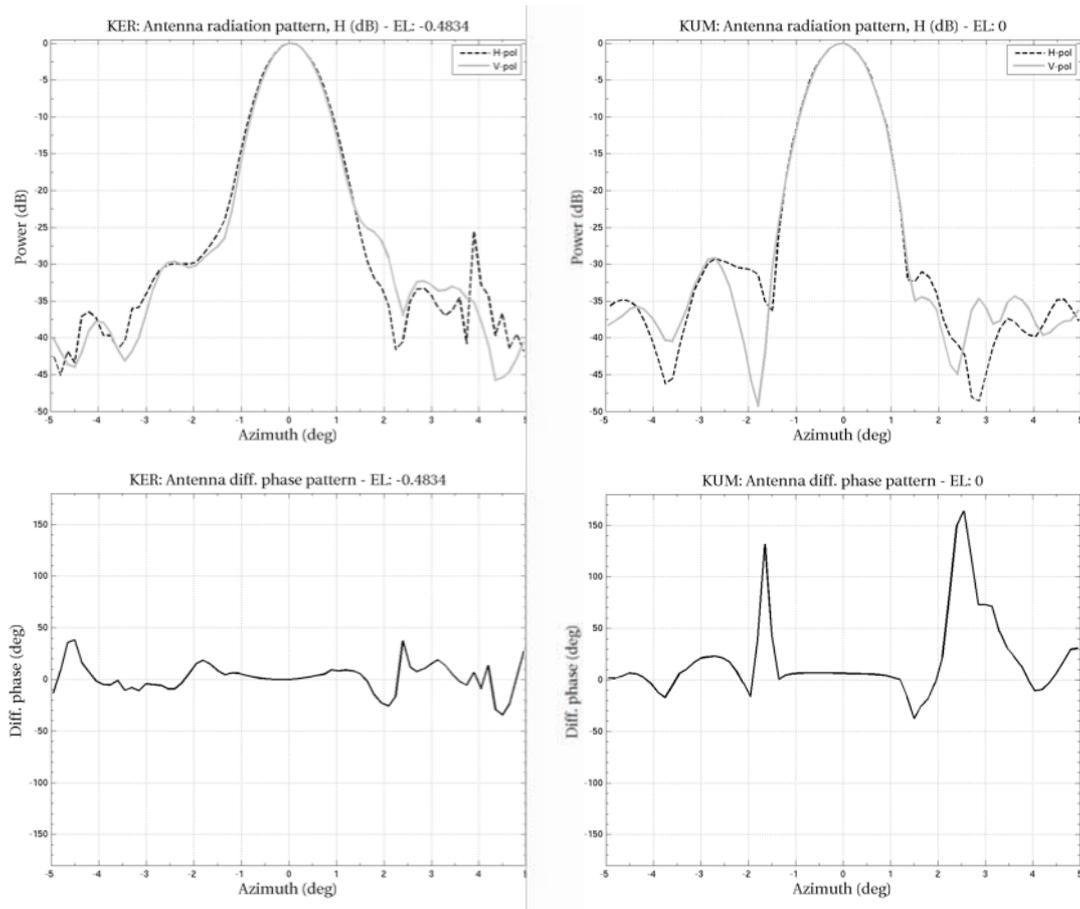


Figure 2. Measured antenna power and differential phase patterns of Kumpula and Kerava radars.

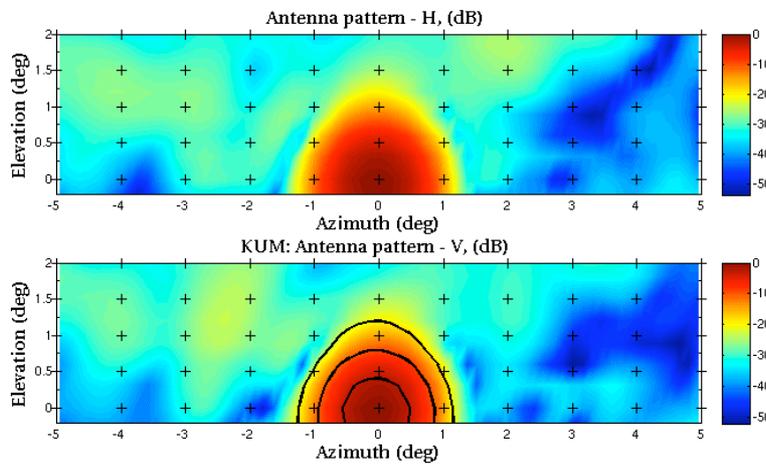


Figure 3 Two-dimensional h- and v- power patterns of Kumpula radar

In Figure 2 measured power and differential phase patterns for Kerava and Kumpula radars are shown. The observations show that both radars have rather good antenna patterns. The power patterns at two polarizations are well matched, down to -20 dB. Furthermore, the differential phase patterns are relatively flat over the main lobe of the antennas.

A more complete picture can be observed by studying the two-dimensional antenna patterns. In Figure 3 two-dimensional h- and v- power patterns are shown. One can see that they are rather similar. By taking a closer look and considering two-dimensional power and phase pattern, as shown in Figure 4, one can see that there are slight variations in both relative power and phase patterns. It is interesting to note that sun observations reveal a similar patter, see Figure 4. This indicates applicability of sun measurements for assessing an antenna dual-polarization performance.

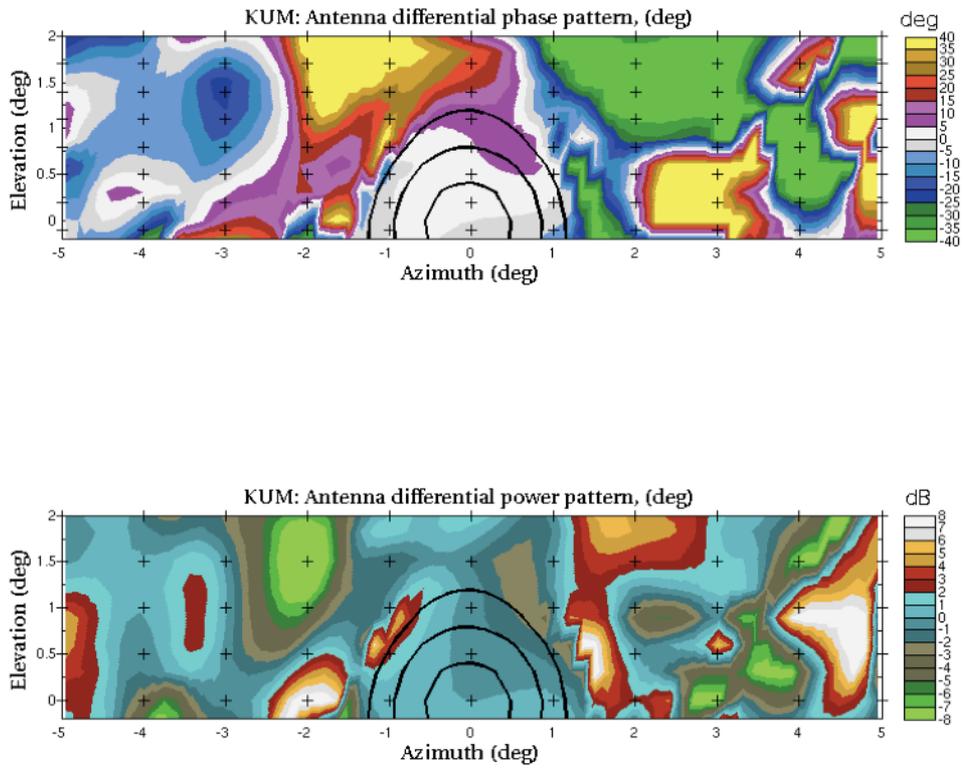


Figure 4. Measured differential phase and power patterns of Kumpula radar.

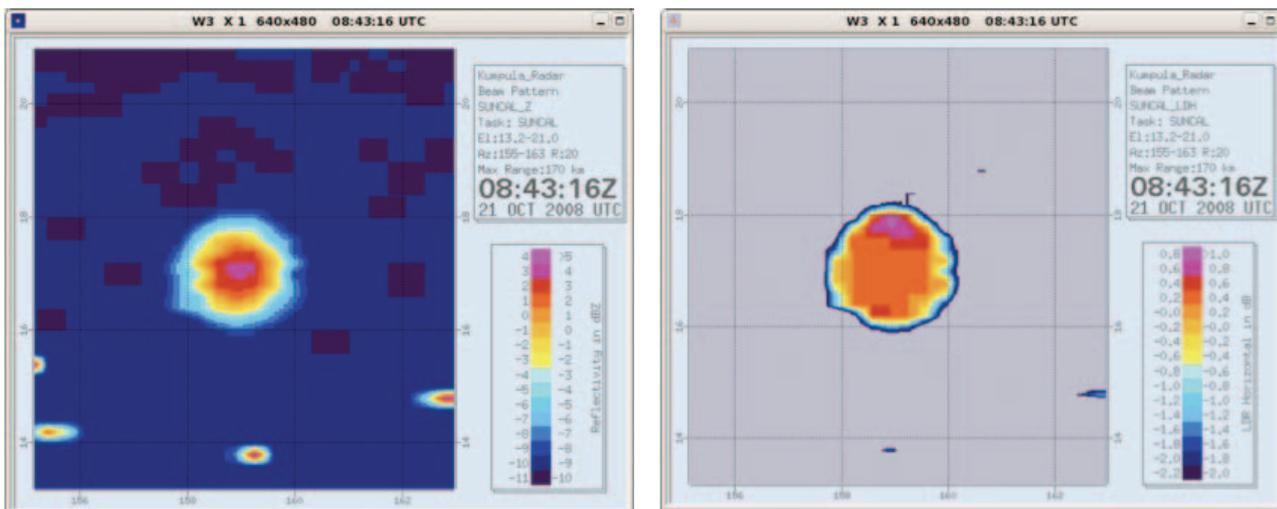


Figure 5. Sun scans using Kumpula radar. Left panel shows observed sun power. The right panel shows measured power ratio between h- and v- power channels.

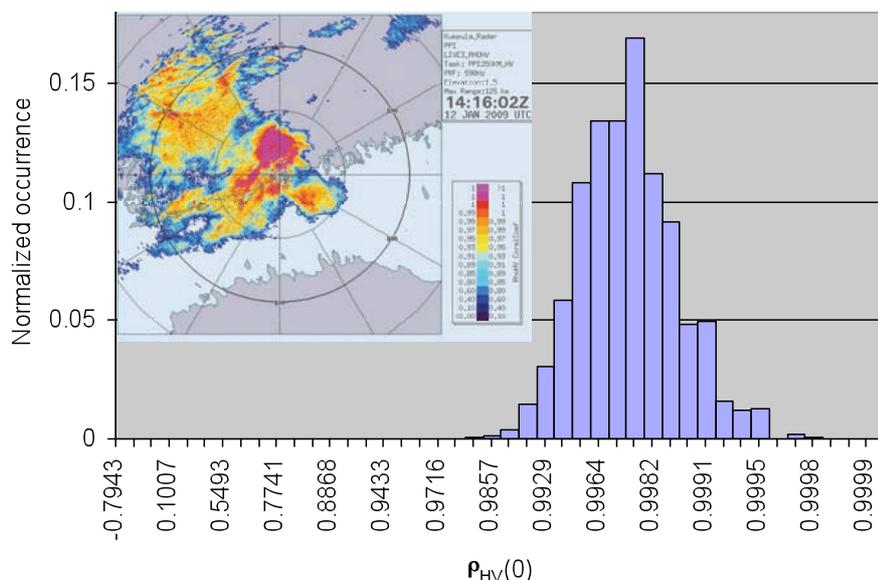
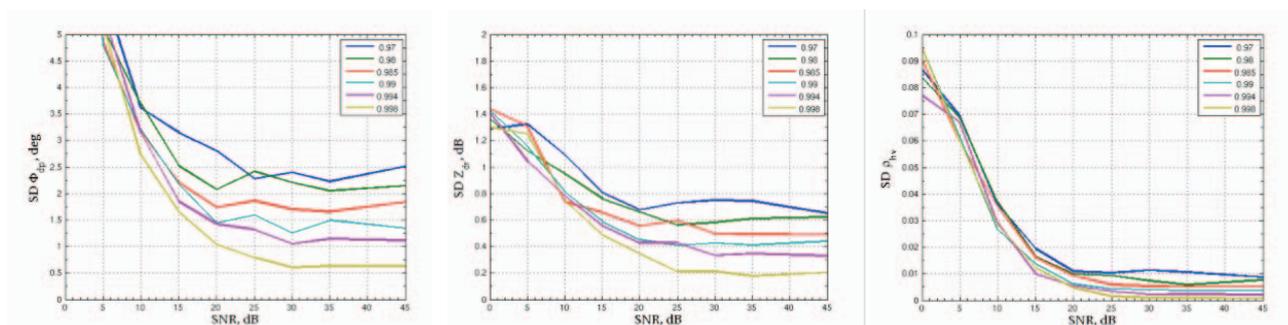


Figure 6. Co-polar correlation observations using radar in light rainfall. The calculated maximum observable co-polar correlation coefficient is 0.998 for the Kumpula radars.

4. Effect on polarimetric radar weather measurements

Figure 7 Simulation based estimates of standard deviations of differential reflectivity, differential phase and co-polar



correlation coefficient for different values of SNR and co-polar correlation coefficient.

Antenna quality is one of the main factors that define a maximum observable co-polar correlation coefficient (Bringi and Chandrasekar, 2001). Given two-dimensional antenna power and phase patterns, one can estimate this coefficient value. Our calculations for Kerava and Kumpula radars show that the maximum observable co-polar correlation coefficient for Kumpula radar is 0.998 and 0.990 for Kerava radar. In Figure 6., Kumpula radar measured values of the co-polar correlation coefficient in a light rainfall are shown. One can see that they are in a good agreement with our calculations.

To analyze how antenna dual-polarization performance affects quality of polarimetric radar observations, we have carried out radar signal simulations (Chandrasekar et al. 1986). For this study time-series radar data was simulated using different values of signal-to-noise ratio and co-polar correlation coefficient. The weather Doppler spectrum was assumed to follow a Gaussian shape with mean fall velocity of 1 m/s and spectrum width of 2 m/s. The polarimetric observables were estimated over 64 samples. In total 100 random realizations of the time-series data were obtained for each SNR and co-polar coefficient value.

In Figure 7 simulation results are shown. One can see that the co-polar correlation coefficient plays a major role in the quality of differential phase, differential reflectivity and co-polar correlation coefficient estimates. For small to moderate SNR values, i.e. SNR smaller than 20 dB, degradation of a co-polar correlation coefficient, for example due to an antenna, from 0.998 to 0.985 is equivalent to reduction in SNR by 3 to 6 dB. For high SNR values, this degradation is equivalent to 10 to 20 dB reduction in SNR. This indicates that for dual-polarization radar observations, antenna performance plays as important, or may be more important role, than a radar transmitter power.

It should be noted that 20 dB SNR at 50 km correspond to a rain rate of about 0.1 mm/hr. Therefore, antenna dual-polarization performance has a dramatic effect on QPE in light to heavy rainfall.

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