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Revolution RADAR

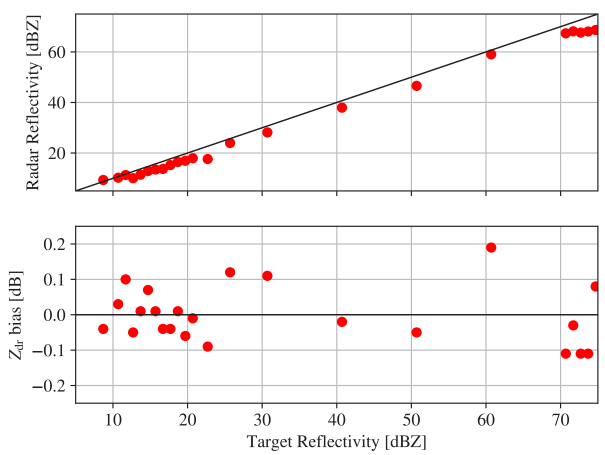
Palindrome Remote Sensing discusses the efficiency and cost-effectiveness of polarimetric weather radar calibration and beyond

Weather radar calibration is a crucial aspect of meteorology, ensuring accurate and reliable measurements of precipitation. In recent years the introduction of dual-polarization radar technology has revolutionized weather radar capabilities. Dual-polarization radar offers enhanced data quality and improved identification of precipitation types.

Calibration enables meteorologists to precisely quantify precipitation rates. This information is vital for flood forecasting, water resource management, and understanding the impact of precipitation on the environment. Calibrated radar systems are crucial for detecting and tracking severe weather phenomena such as thunderstorms, tornadoes and hail. Accurate calibration helps meteorologists to issue timely warnings, thereby enhancing public safety. Proper calibration enables researchers to collect reliable radar data for climate studies, trend analysis and long-term weather monitoring. Consistently calibrated radar systems provide valuable insights into changes in precipitation patterns and climate variability.

While ensuring and maintaining consistent and reliable calibration over a whole radar network has already been a challenge for non-polarimetric radars, the problem has become even more complex with the introduction of dual-polarization systems. The WMO defines acceptable accuracies for the reflectivity factor and the differential reflectivity to 1dBZ and 0.2dB, respectively. Considerable effort and know-how are required to keep a radar network within these boundaries.

BELOW: Comparison between simulated and measured target reflectivity



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Difficulties with standard radar calibration

While radar calibration is essential for maintaining the accuracy and reliability of weather radar systems, there are several challenges associated with traditional, or standard, calibration methods. These difficulties can impact the precision of measurements and hinder the overall effectiveness of radar systems. Sun calibration – i.e. the use of the sun as an external radiation standard – has become one of the most widely used radar calibration techniques in recent years.

While solar calibration is an excellent technique for calibrating a radar receiver as well as for obtaining information on antenna characteristics and pointing, no information can be gained on the behavior of the transmitter. In addition, modern pulse compression weather radars reject noise-like radiation contributions, so that sun calibration measurements can only be applied to the short-range region that is covered by the unmodulated pulse.

Solar calibration is most accurate for S-band radars since solar flux reference measurements are also obtained in this frequency band. For C- and X-band radars, scaling formulas of the reference measurements are needed to obtain data that is comparable to the radar measurements. The fact that the solar signal appears just slightly above the noise threshold, especially at the higher X-band frequencies, further introduces uncertainties and inconsistencies in the calibration process, making it challenging to achieve accurate and repeatable results. Nevertheless, thanks to more than a decade of research and innovation, solar calibration has become a stable solution and one of the main pillars that supports the quality improvement efforts of many European meteorological agencies.

Further, widely used calibration techniques include engineering calibration, i.e. classic determination of radar internal gains, losses and transmitting power, and the use of external calibration targets such as metallic spheres and corner reflectors. The capabilities and limitations of such techniques have been thoroughly discussed in the scientific literature. It is now a common belief that no single calibration technique is capable of addressing all aspects of polarimetric radar calibration.

Standard calibration methods often lack the ability to control or manipulate specific radar parameters. This can hinder the fine-tuning and optimization of radar systems to achieve the desired performance. Without precise control over parameters such as target range, size and velocity, it becomes difficult to thoroughly test and calibrate the radar system under various conditions.

Direct comparability between different radar systems is also an aspect that is difficult to achieve with traditional calibration techniques. Variations in hardware and calibration practices among different radar installations can result in discrepancies in the final determination of the reflectivity bias. This lack of comparability can impede data exchange, integration and collaboration among meteorological agencies.

ABOVE: Third generation instrument from Palindrome taking measurements in Switzerland

Calibration with target simulators

To overcome the challenges associated with standard radar calibration methods, radar target simulators offer a valuable solution. By generating artificial radar echoes with known characteristics, they enable precise adjustments, reproducible targets and comprehensive testing under various conditions. For dual-polarization calibration applications, target simulators ensure the precise control of polarimetric variables such as differential reflectivity (ZDR) and specific differential phase (KDP) within a controlled environment. This enables different radar systems to produce comparable data, supporting collaborative efforts and research initiatives.

Palindrome Remote Sensing is the inventor of the world's first dual-polarization radar target simulator system that specifically addresses the needs of the meteorological radar community. The system is available for S-, C- and X-band frequencies, or optionally as a multifrequency system that covers all three weather radar bands with one single instrument.

After the launch of the first prototype system for the ICE-POP campaign that was conducted during the Olympic Winter Games in South Korea in 2018, the third generation is now ready and offers advantages in handling and accuracy. The new system has been designed for comfortable transportation and deployment and a newly developed graphical user interface facilitates the correct generation of the virtual reference targets. The instrument is equipped with an antenna tracker that autonomously directs the antenna toward the radar under test. These features enable the generation of consistent radar echoes for precise calibration across different radar systems, so that accurate comparison of measurements over time and between different installations are ensured.

Using radar target simulators can streamline the calibration process, reducing the time and resources required, thus enabling more efficient and cost-effective calibration practices.

Green energy with modulated radar targets

In addition to providing precise reference targets for polarimetric calibration, the Palindrome radar target simulator enables the generation of more complex targets for specific weather radar applications. One of many examples is the generation of radar signatures that mimic the presence of wind turbines or even wind parks. It is well known that weather radar data quality can be negatively affected by the presence of wind turbines within the radar's field-of-view. Simulating wind turbines or wind parks with a target simulator supports the testing of advanced signal processing-based mitigation mechanisms and helps to find optimal siting compromises for the benefit of both the radar operators and the producers of renewable and carbon-neutral wind energy. ∎

Polarimetric weather radar calibration