Enhanced Capabilities of SANSA's SuperDARN Radar: Dual-Channel, Interferometry, and Expanded Space Weather Observations

D.van Wyk, M.Kosch, J.Ward
South African National Space Agency (SANSA)

INTRODUCTION

The South African National Space Agency (SANSA) has completed a significant upgrade to its SuperDARN radar system, enhancing both hardware and software components to support next-generation ionospheric research and space weather monitoring. The SANAE SuperDARN radar has transceiver boxes based on the FPGA platform known as Tiger 3. The radar now operates with MABEL 3.0, providing improved data acquisition and control, and has been upgraded to support dual-channel scanning for simultaneous multi-beam observations. Transmission power has been increased to enable detection of weaker backscatter signals at greater ranges, improving the radar's sensitivity to high-latitude plasma convection patterns and ionospheric irregularities. A key addition is the deployment of a secondary antenna array functioning as an interferometer, which enables elevation angle-of-arrival (AoA) measurements.

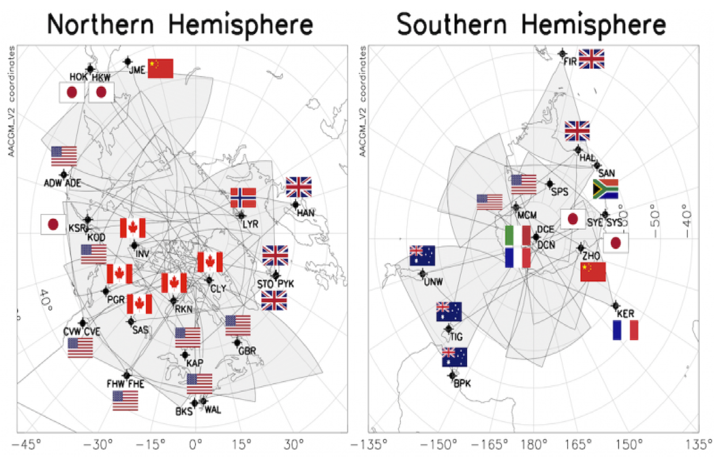


Figure: SuperDARN Coverage Map (2020)

INTERFEROMETRY

The secondary array of the SuperDARN radar also known as the interferometer, consists of 4 individual antennas. The interferometer has been reconstructed during the season of 2023 by the overwintering engineers. The interferometer consists of 14 masts , 12-meters tall with 52 anchor points.

- **Interferometer**: Deployment of a secondary antenna array
- **Enhancement**: Introduction of elevation angle-of-arrival (AoA) capability
- **B**enefits: Vertical ionospheric structure, 3D plasma flow vectors

(a) Cherry Picker Operations, 2025

(b) Antenna and Balun Replacement, 2024

Figure: Fully completed Interferometer, 2024

CONCLUSION

The main array of the SANAE IV SuperDARN array consists of 16 horizontally polarised twin terminated folded dipole antenna which are each connected to a TIGER 3 transceiver box. All the transceiver boxes were modified on board level to accommodate the upgrade of the whole HF radar operation system.

- **New Front Panel** hardware to be developed and integrated. This will allow for a more accurate, remote monitoring and maintenance capability and will allow for the FPGA code to be upgraded remotely as well.
- **S**atellite HF Beacon Project to verify angle of arrival.
- **New FPGA code** to add a listening mode onto of the channels, even with the radar running a SuperDARN program concurrently on the other channel.
- **Experimental transmission schedule** is being run on the HF Radar in order to collect a specified amount of data during an extended period. This data will be utilised to calibrate any off-set values of the new integration of the secondary array with the main array.
- **Transceiver power** was increased from 500V to 550V, delivering approximately 750 Watts of transmit power.

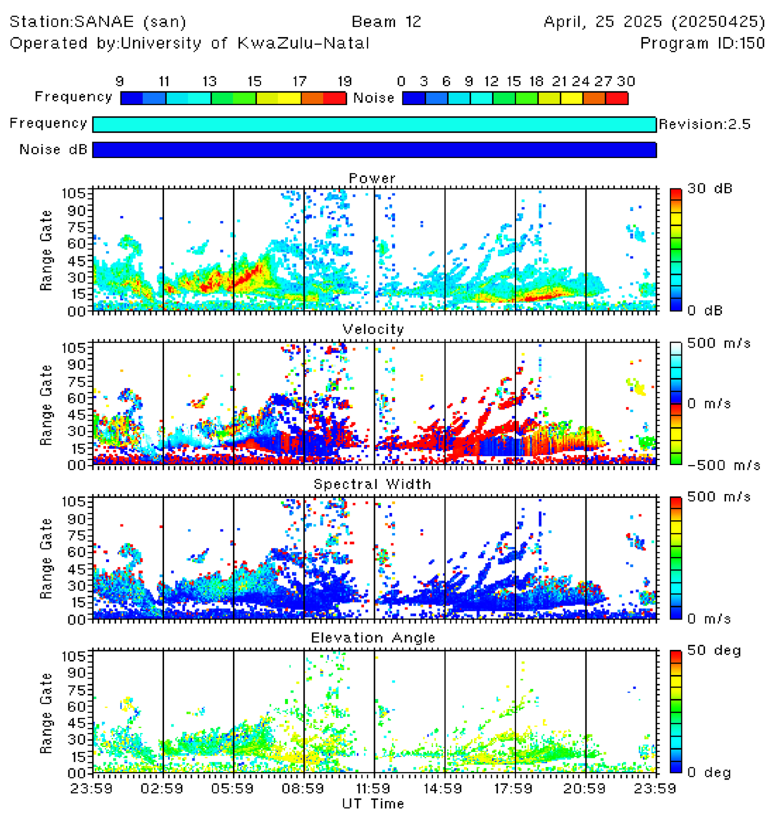
Overall additional improvements are being made to continuously enhance the performance of the radar for accurate measurements.

UPGRADE OVERVIEW

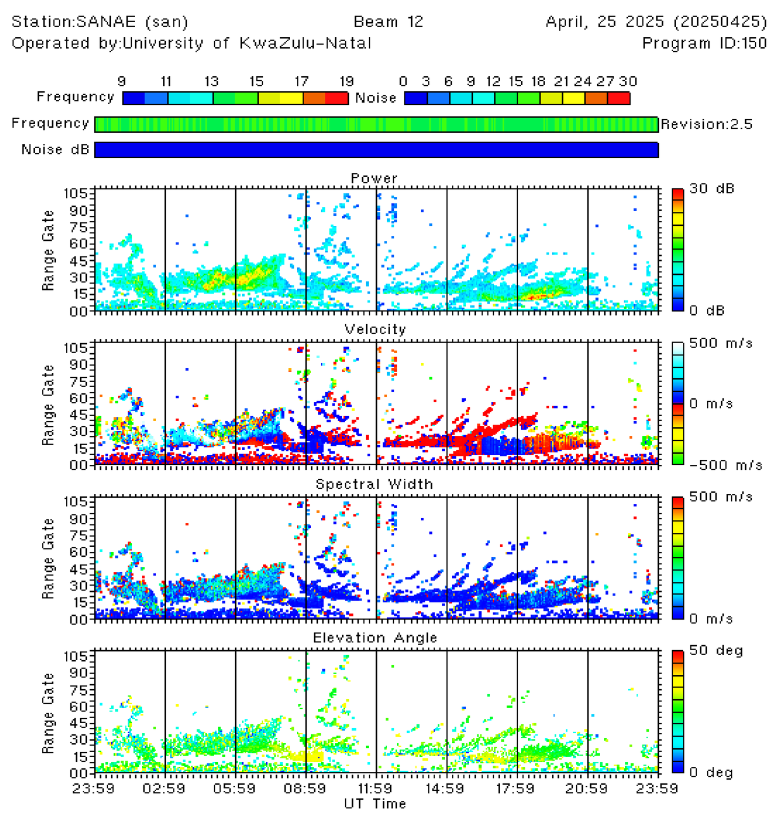
The SANAE IV SuperDARN radar system has been upgraded in 2024 to operate on the new MABEL 3.0 software platform, enabling more advanced radar control and data acquisition. A key enhancement is the introduction of dual-channel scanning, which allows for simultaneous operation on different beam directions using configurable scanning modes—significantly increasing temporal resolution and data throughput.

1. **MABEL 3.0 software**: Improved control and data acquisition.
2. **Dual-channel scanning**: Enables multi-beam observations.
3. **Increased transmission power**: Enhanced range and sensitivity.

The transceiver power was also upgraded during the 2025 season from 500V to 550V, delivering approximately 750 Watts of transmit power. This enhancement improves the radar's sensitivity to weaker backscatter signals and increases the overall range of the radar beams. Furthermore, the integration of a secondary antenna array in 2024 has introduced the ability to measure elevation Angle-of-Arrival (AoA), enriching the data with vertical structuring of ionospheric scatter. The time difference (tdiff) between the RF paths of the main and secondary arrays has been calibrated to -55 μs, a critical parameter for accurate interferometric measurements.



(a) Power, velocity, spectral width and elevation data for Channel A.

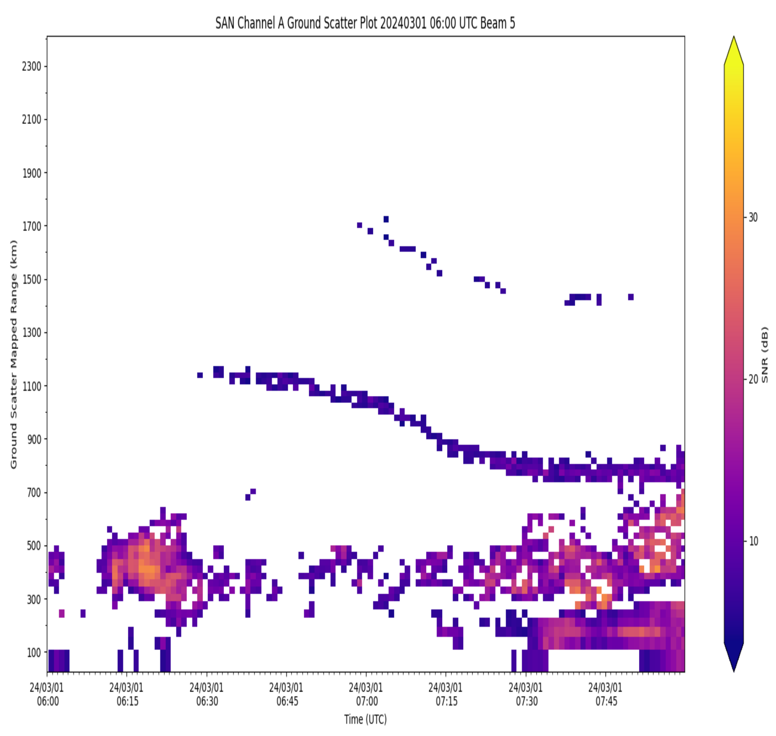


(b) Power, velocity, spectral width and elevation data for Channel B.

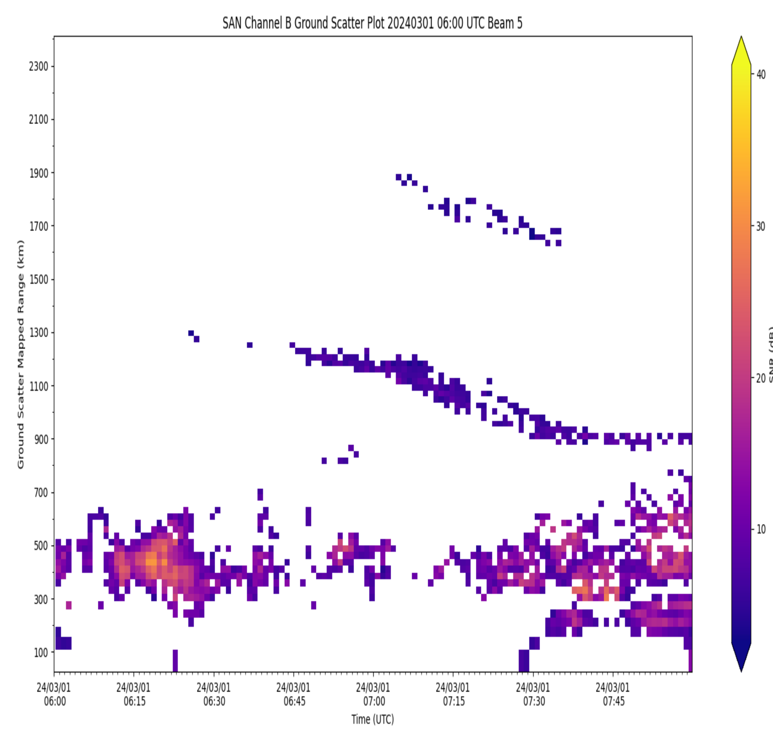
SCIENTIFIC APPLICATIONS

The upgraded SANSA SuperDARN radar significantly enhances scientific investigations of ionospheric and magnetospheric dynamics. With improved resolution and expanded coverage, the radar now produces more detailed convection maps, enabling better modeling of global plasma circulation. It facilitates the detection and tracking of traveling ionospheric disturbances (TIDs), which are critical for understanding thermospheric wave propagation. The increased sensitivity also supports advanced analysis of ultra-low frequency (ULF) wave activity, key to studying energy transfer in the geospace environment. Additionally, the system enables precise monitoring of plasma irregularities and instabilities, and contributes to research on wave-particle interactions, offering deeper insights into coupling mechanisms between different space weather drivers.

- **Improved convection maps**
- **Study of TIDs**
- **ULF wave activity modelling**
- **Plasma irregularities and instabilities**
- **Wave-particle interaction insights**



(a) Ground Scatter Mapped Range for SAN Channel A.



(b) Ground Scatter Mapped Range for SAN Channel B.

FUTURE WORK

To further improve data accuracy, the RF cables on the secondary array are scheduled for replacement during the next voyage season to reduce systematic delay errors. New electronic printed circuit boards (PCBs) will be implemented after successfully testing of prototypes that are part of the upgrade process and new software implementation.

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