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Application of Beam Spoiling for Advanced Operations of SuperDARN Radars

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The Super Dual Auroral Radar Network (SuperDARN) consists of around 40 monostatic over-the-horizon radars operating in the 10-18 MHz frequency band [1, 2]. The network represents a unique research tool for mapping plasma drifts across the mid- and high-latitude ionosphere, which characterise the solar wind–magnetosphere–ionosphere interactions. The standard SuperDARN radars utlise a linear phased antenna array, whose narrow transmit-receive beam consecutively samples 16-24 azimuthal directions within one minute. Such operation modes restrict the signal integration time to only a small portion of the full scan duration and perform non-simultaneous sampling of different directions with the time offset reaching one minute. In this work, we capitalise on the advanced capabilities of the Borealis radar system, which has been recently developed by the SuperDARN Canada group at the University of Saskatchewan [3], to remove such restrictions and to improve the overall performance of SuperDARN radars. As Borealis radars utilise Software-Defined Radio hardware, they allow decoupling transmission and reception and provide flexible antenna array beamforming. We exploited these features to provide simultaneous sampling of all standard azimuthal directions. This was achieved through spoiling the transmission beam by using a non-linear phase progression along the antenna array, which resulted in a wide transmission lobe covering the conventional field of view (FOV). At the same time, the received I&Q signals were recorded for each individual antenna and then post-processed with different linear phase progressions along the antenna array to generate narrow receive beams in multiple directions [4]. Such modifications provided simultaneous sampling of the whole FOV and allowed for an increase in the effective sampling rate by up to 16 times without significant deterioration of data quality. In addition, we also used the wide-beam transmission for the implementation of an efficient multistatic operation mode when ionospheric scatter signals from one radar are also received by other radars with overlapping FOVs. The multistatic propagation geometry required the development of a novel geolocation algorithm, which was based on realistic assumptions about HF propagation at high latitudes. The use of the multiple receive sites allowed for a significant increase in the spatial coverage as compared to the monostatic regime. The different propagation geometry at the additional receive sites also provided independent velocity measurements along different line-of-sight directions, thus allowing to form full Doppler velocity using only a single transmission site. Our future work will focus on radars transmitting at different frequencies so that each radar receives its own echoes as well as signals from the other radars with overlapping FOVs, thus performing both mono- and multistatic measurements from the same site.

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