Radar Imaging of Field-aligned Plasma Irregularities Using Multireceiver and Multifrequency Techniques Implemented in Phased-Array VHF Radars

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Multireceiver and multifrequency imaging techniques, termed coherent radar imaging (CRI) and range imaging (RIM), respectively, have been implemented successfully in phased-array VHF radars for atmospheric sounding. CRI and RIM improve, respectively, angular and range resolutions of the radar targets, providing a deeper examination of the dynamic atmosphere structures at the scales of several to tens of meters. In this study, successful uses of CRI and RIM in the observation of field-aligned plasma irregularities (FAIs) in the mid-latitude ionosphere were demonstrated by using the Middle and Upper atmosphere Radar (MUR; 34.85^{o}N, 136.10^{o}E). Five frequencies equally spaced between 46 and 47 MHz, and 20 receiving channels were employed to implement the radar experiments.

Excellent performance of RIM was able to separate several striations in the clustered FAI echoes, and also to resolve a thin plasma layer to find that the thin layer was structured with tilt striations; these finer structures could not be identified from the original intensity illustrated by 600 meter range resolution. Besides, we found that the RIM results could be applied to identifying the sidelobe echoes arising from the complementary pulse-coding processing. All findings were achieved after effective calibrations of the range/time delay of the signals and the range-weighting function effect on the radar echoes.

On the other hand, the direction of arrival (DOA) of the FAIs, obtained from CRI, exhibited systematic variation with both time and range, which may indicate approximately the drift direction of the FAIs. For example, the zonal DOAs changed alternately between positive and negative values, which could be ascribed to highly localized FAIs drifting zonally through the radar beam. Moreover, the DOAs in elevation were negative and positive, respectively, at higher and lower range locations, which were supposed to be due to meridional drift component of FAIs.

All these measured results support the potential capabilities of CRI and RIM to investigate the dynamic plasma structures in the ionosphere. For example, a combination of five frequencies and nineteen receivers has achieved a 3-D imaging of the FAI structure in the radar volume. Moreover, the declination of geomagnetic line in the radar viewing region could be indicated from the imaged 3-D brightness distribution. The estimated declinations of geomagnetic lines were in consistent with those computed from the International Geomagnetic Reference Field (IGRF) model.