Dual-Polarization Performance of the Phase-Tilt Antenna Array in a CASA Dense Network Radar

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Abstract.- Polarimetric observations are increasingly being considered in weather radar systems. For example, in the US, the NEXRAD system is being outfitted with dual-polarization capability. Moreover, at the X-band wavelengths, the use of polarimetric observations is strongly indicated as one of the primary means to compensating for attenuation. Well matched co-polar beam patterns at vertical and horizontal polarizations and low cross-polarization levels are desired in polarimetric weather radars. At the same time, capabilities of phased-array technology are being investigated for weather radar as part of a multi-function radar mission. While phased-array radars have many advantages in scanning agility, they present a new challenge for polarimetric radars because co-polar main beam patterns, sidelobes and cross-polarization isolation changes with scanning beam position, which can result in higher bias errors in the measured differential reflectivity in comparison with a dish antenna. A new dual-polarized weather radar design concept being investigated by the NSF Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) [1] confronts this phased-array radar issue. The CASA Phase-Tilt radar uses a planar array of dual-polarized columns that performs electronic phase-steering only in the azimuth direction, while mechanically steering in the elevation plane implements polarization diversity through alternating transmit, alternating receive (ATAR) mode [2]. In addition, the CASA paradigm of distributed, collaborative, adaptive sensing (DCAS) means the sensing volume will be covered by a dense network of these radars.

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Since Zdr values range from 0.1dB (drizzle and dry snow) to 3-4dB (heavy rain), it is desirable that the measured bias errors for Zdr be less than 0.1dB. A quantitative evaluation of the measurement accuracy due to system polarization limitations that's convey in a further system specification of polarization requirements for a single conventional dish antenna is described in [3]. According with this analysis, cross-polarization isolation levels better than -20dB and -25dB are needed to avoid contamination of less than 0.1dB in Zdr for alternated and simultaneous polarization modes respectively.

However, satisfying this cross-polarization isolation and match co-polar patterns requirements using phased-array antenna for a large scanning range is not straight forward. A few alternatives to minimize the induced errors due the variability of the E-scan antenna pattern characteristics of V/H with respect to beam position in polarimetric radars are already published. The first one which is described in [4] performs the calibration of the polarization states in order to compensate only the depolarization effect using additional phase-shifter and attenuators. Complex design and cost increment because the additional components (phase-shifters and attenuators) to calibrate the depolarization can be limited factor for this solution. Alternatively in [5], a reduction of the scanning range in H-plane from $\pm 60^o$ to $\pm 45^o$ or to $\pm 30^o$, has been shown a significantly reduction of the bias errors because the mismatch-polar patterns and cross-polarization isolation in comparison sector scan of $\pm 60^o$. Similarly to first approach, a high cost increment is associated with the additional number of panels per node and also more complexity in the system design is required to control more panels per node.

The purpose of this paper is to show that using the CASA dense network approach, the bias errors due the variability of the phased array antenna polarimetric characteristics with respect to beam position does not represent a limiting factor when the radars are configured in dense radar network. This paper presents a quantitative evaluation of bias errors in the Zdr measurement due the errors of the phase-tilt radar array antenna scanning performance for a single node and also for the CASA dense radar in a network configuration. Errors bound due the main beam mismatch, sidelobes roll-off, quantization errors and cross-polarization isolation are presented. Finally a methodology to develop the polarization system requirements using phased-arrays is also discussed.

References

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