Degree of Polarization for Weather Radars

M. Galletti[1], D. H. O. Bebbington[2], M. Chandra[3], T. Börner[1]

[1] Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany
[2] Department of Electronic Systems Engineering, University of Essex, Colchester, Essex, UK
[3] Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany,
(madhu.chandra@etit.tu-chemnitz.de, Tel.: +49 (0)371 531 24340)

Weather Radars are a fundamental tool for National Weather Services. Planned operational systems are likely to include Doppler and dual polarization, whose usefulness has been widely demonstrated in the last twenty years. Such radars will probably implement hybrid polarization, a mode that involves transmitting slant 45° and receiving the horizontal and vertical components of the backscattered signal. The reasons for such a choice are both theoretical and practical. The theoretical assumption is that weather targets most often appear to satisfy mirror reflection symmetry about the vertical axis. Practical considerations that make this choice operationally attractive is that, besides being more expensive, switched systems are characterized by increased feed complexity and more difficult calibration procedures. Further, hybrid polarization was conceived to effectively measure Z_{DR}, KDP and ρ_{HV}, which have been perceived operationally to be useful qualitative and quantitative parameters.
A variable available to dual polarization coherent radar systems is the degree of polarization, obtainable from Wolf's coherency matrix. However, for a given incoherent target, the degree of polarization of the backscattered wave is dependent on the transmit polarization state. To investigate this dependence, we resorted to process fully polarimetric weather radar signatures and compute, from the same dataset, the degree of polarization for different transmit states. A way to measure the degree of polarization capability to capture information from an incoherent target is a confrontation with entropy, a scalar quantity relating to the heterogeneity of statistically independent degrees of freedom existing in the scattering population. As Entropy is designed to capture the whole polarimetric heterogeneity of the scattering population, the minimal degree of polarization (the degree of polarization obtained from the transmit states that minimize its value) is expected to mirror entropy behavior rather faithfully.
A fully polarimetric radar is able to transmit pulses whose polarization state is switched every pulse repetition period (polarization agility) and is set to simultaneously receive the co- and cross- polar components of the backscattered signal (dual receiver). Such a set up allows quasi-simultaneous measurements of the complete scattering matrix. The first meteorological radar designed to measure complete scattering matrices of weather targets was developed at DLR about twenty years ago and is known to the weather radar community as POLDIRAD, acronym for polarization diversity radar. The term polarization diversity refers to its capability of being able to fast-switch on transmit between any pair of orthogonal polarization states. To collect the data presented in this work, POLDIRAD was operated to switch between horizontal and vertical polarization states on transmit, and was set to receive the copolar and cross-polar components of the backscattered signal. This operation mode is called VHVH, but, as pointed out above, other modes are also possible like RLRL using right and left circularly polarized transmissions, as well as hybrid polarization. Ideally, all elements of a scattering matrix should be measured simultaneously. However, since (unless some coding scheme can be used) the transmit polarizations must be emitted sequentially, the scattering matrix measured by a fully polarimetric weather radar is affected by both mean motion of the target and decorrelation due to random displacements of the single scatterers. Mean motion results in a phase offset between the first and second column of the scattering matrix while random motion manifests itself in amplitude and phase fluctuations of the backscattered signal as well as some depolarization. If the second effect cannot be corrected, special signal processing procedures must be applied to correct for the Doppler phase shift.