Ongoing Investigations of Rain Drop Shapes and Oscillation Modes

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Abstract

It is well known that drop shapes as well as their oscillation modes are important factors which affect earth-space propagation, both in terms of co-polar attenuation and the induced cross-polarization (XPD versus CPA). Our understanding of drop shapes for drop diameters larger than 2 mm is now on a firm footing from both 2D-video disdrometer (2DVD) measurements as well as precise wind-tunnel measurements. The agreement between the two sets of measurements was excellent in terms of (a) drop shapes, (b) axis ratio distributions and (c) the increase in oscillation amplitudes with increasing drop diameter.

Drop shapes from 2DVD in natural rain have been determined in several locations, and a thorough examination of the 2DVD camera data have indicated that in the vast majority of the cases, the 'most probable' shapes conform to those arising from the axisymmetric (2,0) mode. There have been a few exceptions, however. A recent study using two collocated 2DVD instruments and the C-band polarimetric radar, ARMOR, in Huntsville has clearly shown that in one event (on 25 Dec 2009) which had a highly organized line convection embedded within a larger rain system, mixed-mode oscillations could be inferred within the line, which in turn were attributed to sustained drop collisions. Inferences were made from the 2DVD camera data which showed a substantial fraction of drops were undergoing asymmetric mode oscillations (i.e., their images did not possess a rotational axis of symmetry) whilst the radar data showed much higher than expected differential attenuation within the line.

A number of recent wind-tunnel experiments of drop collisions (tiny drop with a 3 mm drop) have shown that the horizontal and transverse mode drop oscillations (of the larger drop) greatly enhance in amplitude immediately upon collision and that these modes can last for up to at least 0.3 sec. In the case of the (2,2) mode, the oscillation amplitude increases by a factor of 30. If collisions occur typically at a rate of 0.2 s^{-1} (as has been shown in the past), then it is conceivable that collisions can sustain drop oscillations (against viscous dissipation) for a significant fraction of the 3 mm drops.

In this paper, we present (a) the evidence for the occurrence of mixed mode oscillations in the abovementioned event, and (b) scattering calculations for mixed mode oscillations using an advanced fast numerical technique which uses the method of moments solution to the surface integral equations and enables scattering matrix calculations of asymmetric hydrometers of electrically large (compared to wavelength) sizes. Implications for propagation parameters for typical earth-space link frequencies will be discussed.