1. Introduction: Rain drops and melting hail differ not only in their shapes and sizes but also in terms of their dielectric properties. Previous polarimetric radar observations at C-band have identified regions where a much larger differential attenuation between the horizontal and vertical polarizations have been noted (Tabary et al., 2009). Here we address this by comparing the propagation characteristics of large rain drops with those of a special form of melting hail where the initial stage of melting ice is assumed to occur around the ‘equator’ (as has been observed in wind-tunnel experiments, Rasmussen, and Heymsfield, 1987). Simulations are carried out at C band as well as S and X bands. For C-band, results of specific differential attenuation, differential phase, and differential reflectivity for such hydrometeors have already been published (Thurai et al., 2015). We present the corresponding results for S and X bands, and additionally discuss CSU-CHILL S and X band radar observations during a rain with small melting hail mixed event.

2. Hydrometeor Shapes and Dimensions

Rain drops

Melting Hail: 2 Models (A & B)

Model (A): based on aircraft probe image given in Fig. 7.46 of Bringi and Chandrasekar (2001)

Model (B): based on the 2DVD image obtained during a rain-hail event which occurred in Greeley, CO.

3. Electromagnetic Scattering Modelling

Method of Moments Scattering Analysis

Consider a dielectric scatterer situated in the free space and excited by a time-harmonic electromagnetic field of complex field-intensities \( \mathbf{E}_i \) and \( \mathbf{H}_i \). We use the surface equivalence principle and model the surfaces of a scatterer by means of generalized curved quadrilateral patches of arbitrary geometric orders \( K_s \) and \( K_r \), and described analytically by

\[
\mathbf{r}(u,v) = \sum_{k=0}^{K_s} \sum_{l=0}^{K_r} \mathbf{B}_{kl} u^k v^l \Phi_k \Phi_l, \quad (u,v) \in [-1,1] \times [-1,1]
\]

where \( I \) represent Lagrange interpolation polynomials, and \( \Phi_i \) are position vectors of interpolation nodes. Electric and magnetic equivalent surface current density vectors, \( \mathbf{J} \) and \( \mathbf{M} \), over quadrilaterals in the model are approximated using hierarchical-type vector basis functions of arbitrary current-expansion orders \( N_s \) and \( N_r \).

\[
\begin{align*}
\mathbf{J}(u,v) &= \sum_{n=1}^{N_s} \sum_{m=0}^{N_r-1} \mathbf{a}_{nm} J_n(u,v) B_{n,m}, \\
\mathbf{M}(u,v) &= \sum_{n=1}^{N_r} \sum_{m=0}^{N_s-1} \mathbf{b}_{nm} M_m(u,v) B_{n,m},
\end{align*}
\]

where \( J_n(u,v) \) and \( M_m(u,v) \) are the scattered electric and magnetic fields and \( \mathbf{a}_{nm} \) and \( \mathbf{b}_{nm} \) are dielectric parameters of the considered domain of the scatterer. These equations represent a set of coupled surface integral equations (SIEs) for \( \mathbf{J} \) and \( \mathbf{M} \) as unknowns, which can be discretized and solved for the unknown current-distribution coefficients employing Galerkin method.

4. Results at C-band for Individual Hydrometeors

- C-band results have been published in Thurai et al., 2015.
- For rain \( \rightarrow D_0 \) is chosen to range from 2 to 10 mm.
- For hail \( \rightarrow \) hydrometeors based on model (A), with \( w \approx 16.8 \) mm, \( h \approx 9.7 \) mm and \( t \approx 0.4 \) mm.
- Then dimensions of \( h, w, t \) were varied from 50 – 150 % of the original value.

5. S-band Results: Same calculations for rain drops and hail particles.

For hail, model (B) was also considered, with \( h \sim 2.12 \) mm, \( w \sim 2.5 \) mm, \( t \sim 0.85 \) mm, \( t \sim 0.08 \) mm; then downsize and upsize as before.

6. X-band Calculations

The boundary conditions for the tangential (t) components of the total (incident plus scattered) electric and magnetic field vectors on the boundary surfaces yield

\[
\begin{align*}
\mathbf{E}_i &\mid_{z=0} = \mathbf{E}_s + \mathbf{E}_r, \\
\mathbf{H}_i &\mid_{z=0} = \mathbf{H}_s + \mathbf{H}_r,
\end{align*}
\]

where \( \mathbf{E}_s \) and \( \mathbf{H}_s \) are the electric and magnetic fields and \( \mathbf{E}_r \) and \( \mathbf{H}_r \) are the scattered electric and magnetic fields.

\[
\begin{align*}
\mathbf{E}_i &\mid_{z=0} = \mathbf{E}_s + \mathbf{E}_r, \\
\mathbf{H}_i &\mid_{z=0} = \mathbf{H}_s + \mathbf{H}_r,
\end{align*}
\]

The results for the larger hail particles show a ‘wall’ of negative \( Z_D \) well below -3 dB at \( \sim 30 \) km range which may well be scattering effects, c.f. our results for the larger hail particles.

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References:


