Determining MU radar meteor properties with a new pulse-to-pulse phase correlation technique

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Meteor head echoes are radio wave reflections from the dense plasma created by and surrounding a meteoroid on its way through the atmosphere. We have developed an analysis scheme for meteor head echoes detected with the Shigaraki 46.5 MHz MU radar, where we combine the velocity estimated by target range rate and Doppler shift from a single pulse with the correlation of the phase of each echo pulse-to-pulse. The precision is of the order a few tens of m/s, which is an improvement of more than a factor of 20 as compared to single pulse analysis and allows very precise velocity and deceleration determination. The interferometric capability of the radar is utilized to determine the trajectory of the meteoroid, and thus also the instantaneous angle between the trajectory and the line-of-sight to the centre of the transmitter/receiver antenna field. This angle is taken into account on a pulse-to-pulse basis to calculate the true meteoroid velocity along its trajectory and determine its deceleration. Furthermore, the position of the target in the beam is used to estimate the radar cross section by deconvolving the antenna radiation pattern from the measured signal.

The phase velocity is ambiguous with an ambiguity determined by the product of the pulse repetition frequency and one half radar wavelength, which with our experimental settings is about 1 km/s. The single pulse analysis is used to determine which set of the ambiguous values is correct in a robust multi-step procedure. The very precise deceleration and estimated radar cross section of each event are compared with the output of a numerical ablation model in which we simulate each meteoroid's atmospheric flight from the top of the atmosphere down to the measurement volume. By searching the best fit between model and data we inversely estimate meteoroid mass and atmospheric entry velocity of detected meteors.

On March 30-31, we have tried four different set of observation mode with the MU radar, by changing pulse length, IPP, and pulse compression codes, and have determined the best mode out of them. The regular base (routine) meteor observation using this mode will create a very useful and unique data base for studying characteristics of small sporadic meteors and their flux, which would be beneficial for both atmospheric and meteor scientists. Furthermore, the presented analysis technique can be utilized to improve velocity estimations also of other Doppler shifted hard targets than meteor head echoes and can also be utilized at other radar facilities.