Meteoroid Speed and Trajectory Determination from Amplitude and Phase Information of the BRAMS Forward Scatter Radio Network.

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Abstract: In this project, we aim to reconstruct meteoroid trajectories thanks to a forward scatter radio system using a pure continuous wave (CW) transmitted signal with no modulation. To do so, we use the meteor echoes recorded at the receivers of the BRAMS (Belgian RAdio Meteor Stations) network. The latter is made of a dedicated transmitter and currently 44 receiving stations located in and nearby Belgium, all synchronized using GPS clocks.

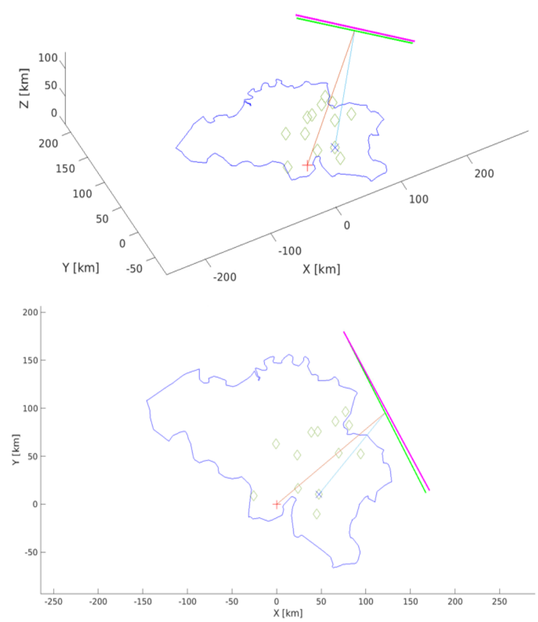
The reflection on the plasma trail left behind the meteoroid is usually assumed to be specular, which means that the radio wave is reflected only at a given point along the meteoroid trajectory. For forward scatter systems, the position of this specular point depends on the trajectory on the one hand, and on the position of both the transmitter and the receiver on the other hand. Using non-collocated receivers, one obtains several specular points along the meteoroid path. The receivers will thus detect the reflected signal at different time instants on a given trajectory.

Our approach processes the meteor echoes at the BRAMS receivers and uses the time delays as inputs to a nonlinear optimization solver. We compare the quality of our reconstructions data to the trajectories given by the optical CAMS (Cameras for Allsky Meteor Surveillance) network in Benelux. To do so, we solve the general CW forward scatter trajectory reconstruction problem, but we highlight its strong ill-conditioning if the only inputs are the time delays of the echoes at the receivers.

The BRAMS network also includes an interferometer in Humain (south of Belgium). Unlike the other stations, it allows to determine the direction of arrival of the meteor echo to within approximately 1°. In that case, this high sensitivity to the inputs is alleviated and the reconstructed trajectories are in good agreement with optical ones. However, the interferometer cannot be used for every meteoroid passing above Benelux because of the specular condition.

To obtain a better accuracy for a large number of meteoroids, the trajectory reconstruction with time delays only can be complemented by information about the signal phase. The method used for this work is based on the pre-t0 phase technique introduced by [1], and later improved by [2] for backscatter radars. This approach is based on the phase of the meteor echo before the specular point. In this project, we extend and adapt the method to forward scatter systems and we illustrate the improved accuracy that it brings on the meteoroid trajectory and speed reconstruction.

Figure: Example of trajectory reconstruction using time delays and interferometry. Top panel: projected view in the horizontal plane. Bottom panel: 3D view. The green line is the CAMS trajectory. The blue cross is the reference station (Humain). The red plus is the transmitter (Dourbes). The light green diamonds are the stations used for the BRAMS reconstruction. The orange and light blue line represent respectively the radio wave path from the transmitter to Humain specular point, and the radio wave path from this specular point to the receiver in Humain. The purple line is the reconstructed trajectory with the BRAMS signals. The blue line represents the Belgium border.



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