Theory and Applications of VHF Meteor Radar Observations

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Contents

Abstract

This thesis examines the operation and observations made by VHF interferometric radar. Broad topics include the operation of interferometric meteor radar, the physics of meteor ablation, the formation and diffusion of meteor trails, and meteor astronomy.

The performance of the basic radar configuration is examined with particular attention paid to the source and mitigation of positional errors introduced by hardware. Sources include random errors in phase and range estimates, mutual coupling between antennas, and biases in the phase measurements used to determine the angle-of-arrival of incident radiation. A new method for post-statistical steering is presented, using height dependent ambipolar diffusion coefficients as a reference.

The physics of meteor flight and ablation in the atmosphere is examined in detail. The heating and vaporization of meteoroids as they enter Earth's atmosphere is modeled and the effect of sputtering on the formation of meteor ionization is assessed. These calculations are performed for a variety of meteor types, sorted by velocity, angle-of-entry, composition, and size. The results are then used in conjunction with atmospheric models to produce predictions of meteor radar performance.

The effect of the atmosphere on the ablation and subsequent detection of meteors is considered and used to construct new metrics for the characterization of the atmospheric density profile in the meteor region. The effects of constant density level and density scale height are assessed with regards to the peak detection height and range of heights over which a radar detects meteors.

The formation of the underdense meteor echo is examined in detail. New contributions to the understanding of this topic include an assessment of the effects of variable

electron line density in the trail, deceleration, and fragmentation on the eventual measurement of the decay time of meteor echoes. Estimates of ambipolar diffusion coefficients are examined by determining the effect of anomalous diffusion resulting from electron absorbing aerosols and multi-constituent trail chemistry.

Meteor astronomy techniques used to overcome the limitations of interferometric meteor radars are implemented in order to search for discrete streams of solar system debris that result in meteor showers. The results include a significant number of previously undiscovered shower systems.

I certify that this work contains no material which has been accepted for the award of any degree or diploma in any university or tertiary institution and, to the best of my knowledge, contains no material previously published or written by another person, except where due reference has been made in the text.

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Signed .... date ....

Joel P. Younger, BSc (Hons.)

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Finally, I would like to thank Kelley, for what is my favorite piece of academic prose: "The immediate and incredulous conclusion was that the rocket had penetrated a meteor trail, an event so unlikely as to be embarrassing to report." [Kelley et al., 1998]. Charged dust in the mesosphere is not typically a source of comedy, but I laugh every time I read that passage. Bravo, sir. Bravo.

If anyone has not been mentioned, or not mentioned by name, I apologize. There are so many that deserve my thanks.