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An analytical model for dust impact voltage signals, and its application to STEREO/WAVES data

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Dust grains are a common constituent of the Solar system. Dust impacts have been observed using radio and wave instruments onboard spacecraft since the 1980s. Voltage waveforms show typical impulsive signals generated by dust grains. We aim at developing models of how signals are generated to be able to link observed electric signals to the physical properties of the impacting dust. To validate the model, we use the Time Domain Sampler (TDS) subsystem of the STEREO/WAVES instrument which generates high-cadence time series of voltage pulses for each monopole. A model that we propose takes into account impact-ionization-charge collection and electrostatic-influence effects. It is an analytical expression for the pulse and allows us to measure the of amount of the total ion charge, the fraction of escaping charge, the rise timescale, and the relaxation timescale. The model is simple and convenient for massive data fitting. To check our model's accuracy, we collected all the dust events detected by STEREO/WAVES/TDS simultaneously on all three monopoles at 1AU since the beginning of the STEREO mission in 2007. Our study confirms that the rise time largely exceeds the spacecraft's short timescale of electron collection. Our estimated rise time value allows us to determine the propagation speed of the ion cloud, which is the first time that this information has been derived from space data. Our model also makes it possible to determine properties associated with the electron dynamics, in particular the order of magnitude of the electron escape current. The obtained value gives us an estimate of the cloud's electron temperature — a result that, as far as we know, has never been obtained before except in laboratory experiments. Furthermore, a strong correlation between the total cloud charge and the escaping charge allows us to estimate the escaping current from the amplitude of the precursor, a result that could be interesting for the study of the pulses recently observed in the magnetic waveforms of Solar Orbiter or Parker Solar Probe, for which the electric waveform is saturated.