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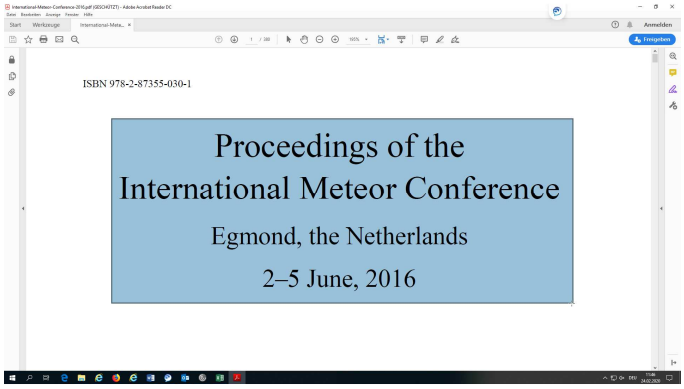

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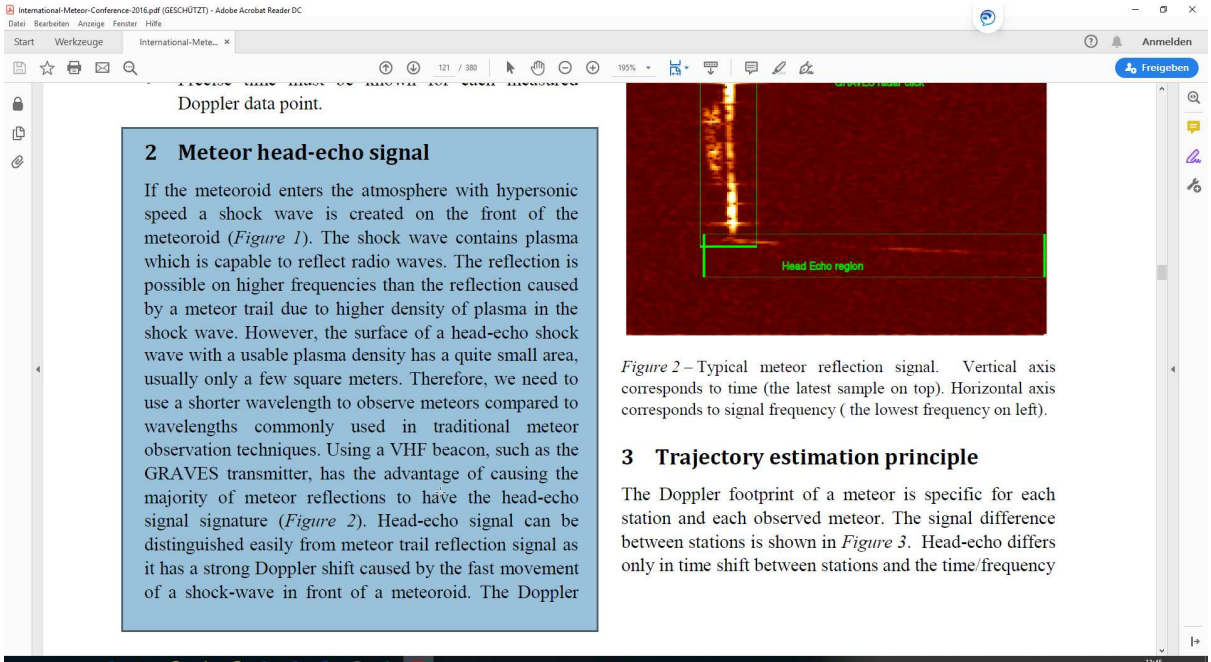


Doppler data point.

## 2 Meteor head-echo signal

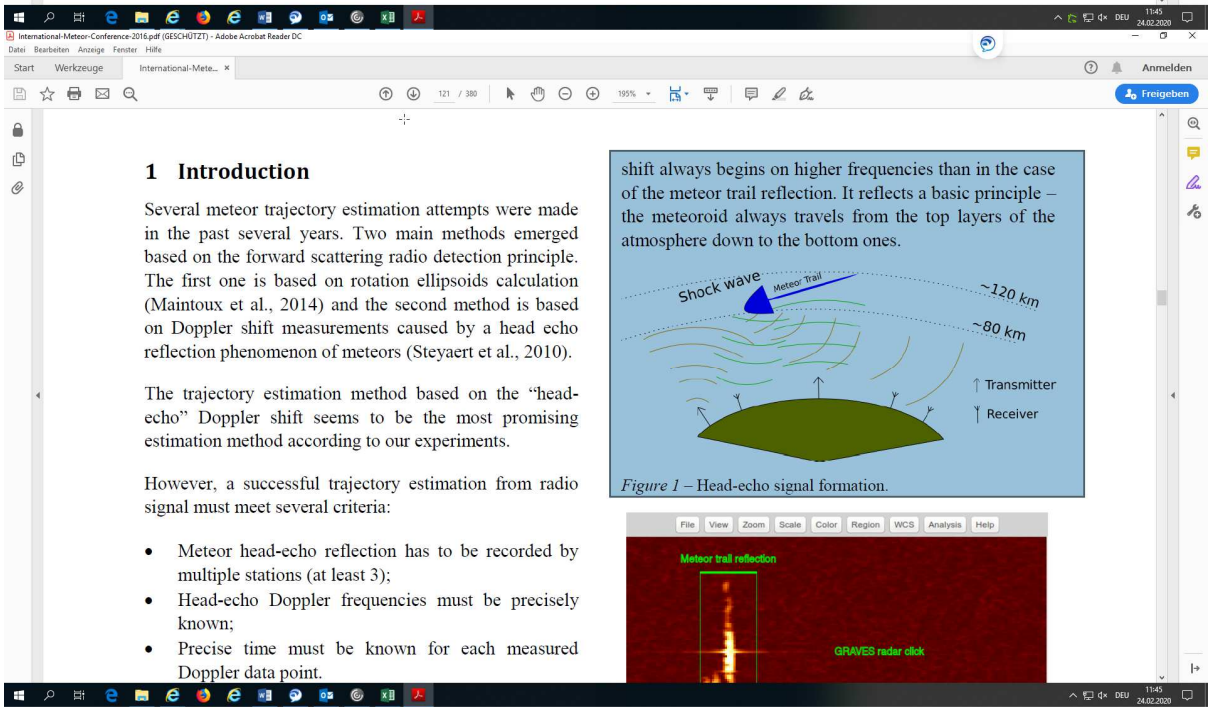
If the meteoroid enters the atmosphere with hypersonic speed a shock wave is created on the front of the meteoroid (*Figure 1*). The shock wave contains plasma which is capable to reflect radio waves. The reflection is possible on higher frequencies than the reflection caused by a meteor trail due to higher density of plasma in the shock wave. However, the surface of a head-echo shock wave with a usable plasma density has a quite small area, usually only a few square meters. Therefore, we need to use a shorter wavelength to observe meteors compared to wavelengths commonly used in traditional meteor observation techniques. Using a VHF beacon, such as the GRAVES transmitter, has the advantage of causing the majority of meteor reflections to have the head-echo signal signature (*Figure 2*). Head-echo signal can be distinguished easily from meteor trail reflection signal as it has a strong Doppler shift caused by the fast movement of a shock-wave in front of a meteoroid. The Doppler



*Figure 2* – Typical meteor reflection signal. Vertical axis corresponds to time (the latest sample on top). Horizontal axis corresponds to signal frequency ( the lowest frequency on left).

## 3 Trajectory estimation principle

The Doppler footprint of a meteor is specific for each station and each observed meteor. The signal difference between stations is shown in *Figure 3*. Head-echo differs only in time shift between stations and the time/frequency



## 1 Introduction

Several meteor trajectory estimation attempts were made in the past several years. Two main methods emerged based on the forward scattering radio detection principle. The first one is based on rotation ellipsoids calculation (Maintoux et al., 2014) and the second method is based on Doppler shift measurements caused by a head echo reflection phenomenon of meteors (Steyaert et al., 2010).

The trajectory estimation method based on the "head-echo" Doppler shift seems to be the most promising estimation method according to our experiments.

However, a successful trajectory estimation from radio signal must meet several criteria:

- Meteor head-echo reflection has to be recorded by multiple stations (at least 3);
- Head-echo Doppler frequencies must be precisely known;
- Precise time must be known for each measured Doppler data point.

shift always begins on higher frequencies than in the case of the meteor trail reflection. It reflects a basic principle – the meteoroid always travels from the top layers of the atmosphere down to the bottom ones.



*Figure 1* – Head-echo signal formation.