TWO HEADS ARE BETTER THAN ONE: ADVANTAGES OF THE BIRAL BACK SCATTER HEAD FOR PRECIPITATION CLASSIFICATION

Automatic visibility and present weather sensors normally use the forward scattering of infrared light to estimate visibility and classify precipitation. Sensors produced by Biral emit a cone of modulated near infrared (850 nm) from the transmitter head, which is scattered by particles in the air. The intensity of scattering is not the same in all directions, since this is strongly dependent on the shape, size and composition of the particle.

Infrared light emitted by the transmitter that is scattered by 39-51° is detected by the forward scatter receiver. This is sufficient to estimate the visibility and aid the classification of precipitation type. The infrared light which is scattered by 107-119° is detected by Biral's unique back scatter receiver, which is used in addition to the forward scatter measurement to help discriminate between different types of precipitation, such as rain and snow. A diagram of the scattering angles in relation to a Biral visibility and present weather sensor is shown in Figure 1.

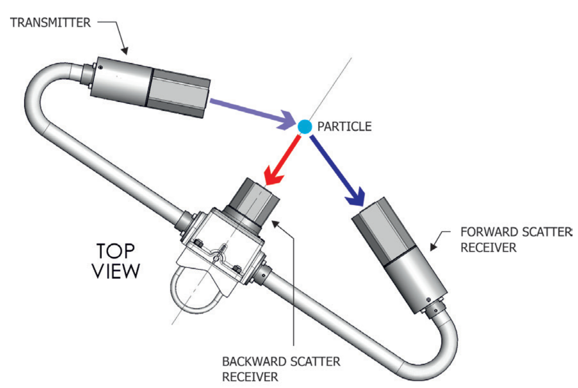

Figure 1: Top view of a Biral present weather sensor showing transmitted and scattered near infrared paths.

Present weather sensors which do not have a back scatter receiver usually discriminate between rain and snow using only the forward scatter signal from an individual hydrometeor (raindrop or snowflake), often combined with air temperature. The signal depends on the particle's size, shape, composition and speed. Generally, it is the size (relating to peak amplitude) and speed (signal duration) which are used for precipitation classification. For example, the Gunn-Kinzer relationship can be used to relate raindrop size and terminal velocity, with measured deviations from this relationship attributed to different hydrometeors. Difficulties with this method arise when snowflakes are blown by a strong wind, which increases their speed and their likely misclassification as heavy rain. Additionally, raindrops which have slowed down due to upward wind flow near the sensor (such as turbulence from nearby buildings), or droplets falling from higher structures nearby which will not have reached "terminal velocity", might be misclassified as snow. Other hydrometeor types are also difficult to distinguish on size and speed alone, such as ice pellets, which have a similar fall speed and size as rain. Air temperature is also commonly used in the precipitation classification algorithms, for example in the differentiation between rain, freezing rain and snow. Whilst offering a sensible constraint to the choice of precipitation type significantly above or below 0°C, ambiguity arises at temperatures close to freezing and when near-surface air temperature is not necessarily representative of the temperature profile further aloft.

Biral's back scatter receiver provides more detailed independent data on the precipitation type compared with using forward scatter alone. Specifically, the sensor measures the ratio between the back and the forward scattered infrared. Snow has a much higher proportion of back scattered infrared compared to rain (figure 2), so the back scatter head is able to reliably differentiate between rain and snow.

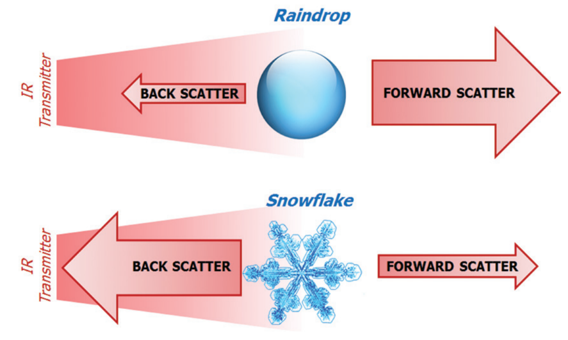

Figure 2: Different forward and back scattered relative intensities for rain and snow.

The crystalline structure of a snowflake provides multiple facets for scattering of optical and infrared light in all directions irrespective of wavelength, especially back towards the transmitter. This accounts for the main reason a human observer can differentiate between rain and snow – because snowflakes are white! The same applies to other frozen hydrometeors such as ice pellets and hail, where back scatter from trapped air bubbles make the particle appear opaque, with increased backscatter. An example of the relative difference between forward and back scattered infrared for different individual hydrometeors is presented in figure 3. These measurements were taken as rain turned to ice pellets then snow as a thunderstorm passed over a Bristol-based sensor on 2 March 2016. Classifications were based on human observation, with approximately three minutes between the different hydrometeor types. Air temperature remained above freezing throughout, at 6°C during the rainfall and ice pellets, and 5°C

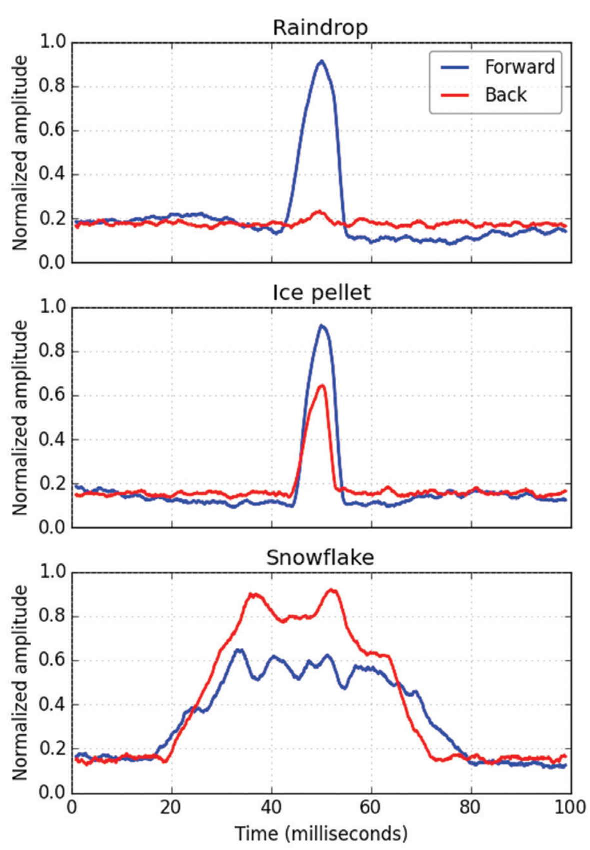

Figure 3: Measured near infrared (850 nm) forward and back scattered amplitudes for different individual hydrometeors as they travelled through the sample volume of a Biral VPF-750 present weather sensor. These measurements were taken as rain (top plot) turned to ice pellets (middle plot) then snow (lower plot) during a thunderstorm over Bristol, UK on 2 March 2016.

during the snowfall. It can be clearly identified from Figure 3 that the relative intensities of the hydrometeor types produce significantly different forward and back scattered signals as they travelled through the sample volume of a Biral VPF-750 present weather sensor. Although the forward scatter signals of the raindrop and ice pellet appear nearly identical, they differ greatly in the relative amount of back scatter. The signal from the snowflake produced the greatest relative back scatter and was approximately five times longer due to its increased size and slower fall speed compared to the raindrop and ice pellet. The variability of the signal amplitudes scattered by the snowflake are likely to be due to its irregular shape as it tumbles through the sample volume.

The back scatter receiver is unique to the Biral present weather sensors and provides reliable discrimination between rain and snow. This is demonstrated by reports of excellent snow-detection and discrimination capability from our customers and field trials with trained meteorological observers. Back scatter receivers form part of our SWS 200 and 250 series and VPF 730 and 750 series. The Biral VPF-750 represents our most advanced visibility and present weather sensor, with the addition of external temperature and relative humidity sensors to aid discrimination between fog and non-liquid particles which lower the visibility, such as smoke, wind-blown sand and dust. An integrated freezing rain detector allows reporting of all forms of freezing precipitation, providing a comprehensive and reliable account of present weather for all environments.

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