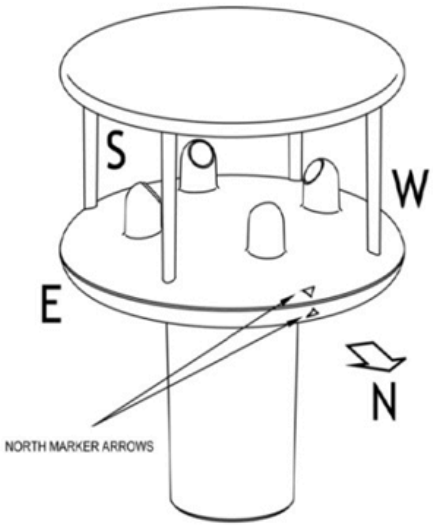
Primer on Ultrasonic Wind Measurement Systems



An anemometer is a common instrument at a weather station. It is used to measure the wind speed and wind direction. The most common type of anemometer uses mechanical sensors consisting of three or four hemispherical cups mounted on horizontal arms on a vertical rod. As the wind blows, the cups are pushed causing the arms to rotate at a rate proportional to the wind speed. In addition, a wind vane connected to the anemometer can give the direction measurements. While the cup and vane anemometers are very popular due to their very simple design, they can be susceptible under cold and humid conditions because of their mechanical rotating parts, possibly causing the turbine to stop operating during extreme conditions. Designed without any moving parts, the ultrasonic anemometers are more reliable, maintenance free, long-lasting, and can operate in challenging weather conditions. In this article, we will review the basic working principle of an ultrasonic anemometer.

Working principle of ultrasonic wind sensor

A typical ultrasonic anemometer consists of 2 pairs of ultrasonic transducers mounted at right angles to one another as shown in the figure above. Each sensor is capable to transmit and receive ultrasonic pulses. The physical distance between the opposite facing sensors is fixed and known. During operation, the time taken for an ultrasonic pulse of sound to travel from the North (N) transducer to

the South (S) transducer is compared to the time for a pulse to travel from S to N transducer. If there is no wind blowing, the two times should exactly match. Otherwise, the sound wave traveling with the wind should arrive earlier than the sound traveling against it. For example, if there is a wind blowing to N, the N to S travel time would be more compared to the S to N travel time. The difference in the time of flight can give the relative speed of wind along NS axis. Similarly, flight times are also compared along the East-West and West-East directions to compute the wind velocity along the EW axis. The two rectangular velocity components of the wind are then combined to compute the wind vector with a resultant sum and an angle of wind velocity. The sensor arrangement shown above gives only the horizontal wind speed. Measuring a three dimensional wind speed requires sensor arrangements along the vertical direction too.

Sonic Anemometers – Basic Concept:

- Determines the *wind vector* my measuring the ***flight time of sound pulses*** travelling forward and backward between two fixed transducer / receiver pairs (A and B below) separated by < 20 cm
- Estimates *wind speed component parallel to the path*
- Multiple fixed-angle transducers (and some trigonometry) are used to obtain the two / three dimensional winds

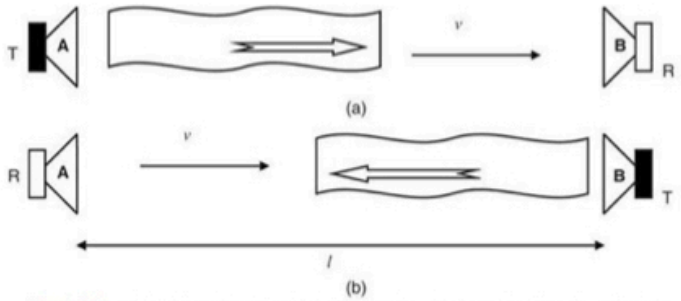


Figure 8.6 Conceptual arrangement of a one-dimensional sonic anemometer, with reversible transducers A and B spaced a distance *l* apart, each able to act as a transmitter (T) or receiver (R) of ultrasound. The pulse of ultrasound travels at the speed of sound and is propagated forwards (a) and backwards (b), encountering a wind speed *v* which adds or subtracts from the speed of sound accordingly.