-power in control

WSS/WSS-L

White paper

- Ultrasonic Wind Sensor Technology

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1. About this document

General purpose

Feeling comfortable when using new advanced technology is very closely related to understanding the basic principles of how it works. At DEIF we therefore hope this document will bring that understanding and comfort, to enjoy and benefit from the front edge technology used in the WSS sensor.

2. DEIF WSS and WSS-L Ultrasonic Sensor Technology

The theory of operation

The principle described in the following is for both WSS and WSS-L

WSS sensors use an array of three ultrasonic transducers oriented so that the paths between the transducers form an equilateral triangle. Wind measurement is based on time of flight (TOF), the time it takes for an ultrasonic signal to travel from one transducer to another. TOF is measured in both directions for each pair of transducer heads. The parallel component of wind velocity can be determined for each transducer pair by comparing the TOF of ultrasonic signals in opposing directions. In zero wind, TOF for all ultrasonic signals is the same. As wind increases, disrupting the medium through which the ultrasonic signal travels, TOF values begin to diverge. The processing of these TOF values enables accurate calculation of wind speed and direction.

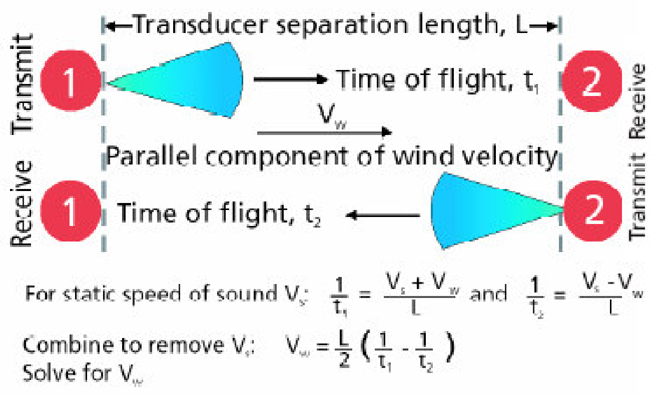

Figure 1.
Time-of-flight for a sonic impulse from the transmit transducer to the receive transducer is determined for both directions. Simple algebra allows solving for the parallel component of wind velocity independently of the static speed of sound.

Ultrasonic transducers normally operate in the frequency range from 100 kHz to 300 kHz; the WSS is operating at 270 kHz. A measurement cycle consists of each transducer sending 16 ultrasonic pulses to the other two transducers, resulting in 96 TOF measurements. As many as four measurement cycles can be completed in one second. Although atmospheric conditions affect the speed of sound and therefore the TOF, the speed of sound at any given moment is static and its effect is cancelled algebraically when calculating parallel component of wind for each pair of transducers.

The triangular configuration of the WSS sensor and the bi-directional TOF measurements for each pair of transducers provide three sets of basis vectors. Only two basis sets are necessary to determine wind speed and direction. The WSS measurement strategy is to evaluate the quality of each basis set and select the two best basis sets to be used for calculation. The quality of a basis set is determined by statistical analysis of TOF data.

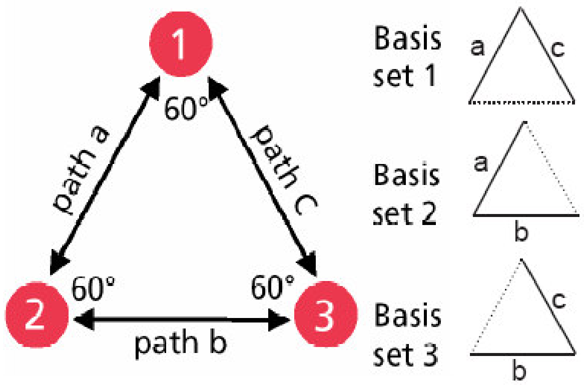

Figure 2.
The equilateral triangle configuration of the three transducers provides three possible sets of basis vectors. The combinations yield bi-directional measurements on the paths labeled a, b and c. These measurements are used to determine the wind velocity components parallel to each of the three paths.

Quality criteria includes the number of successful measurements for each measurement path, the standard deviation of TOF values for each path, and the TOF average values for each path. The triangular configuration of WSS transducers assures that two good basis sets are always available for any set of wind conditions. If wind direction is exactly parallel to one set of transducers, turbulence will distort the TOF measurements and create a flawed basis set, but data from the remaining two sets of transducers will be valid.

The Equilateral Triangle Design versus Orthogonal Design:

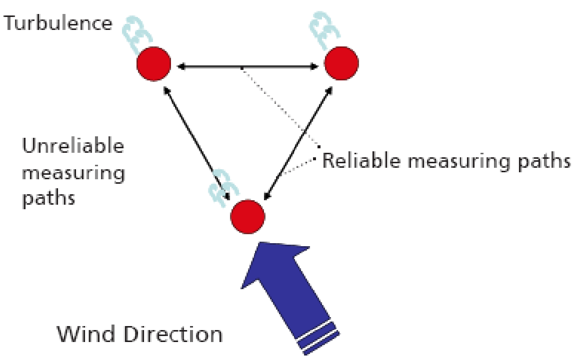

Figure 3.
The sensor's equilateral triangle design assures two good basis sets in all wind conditions.

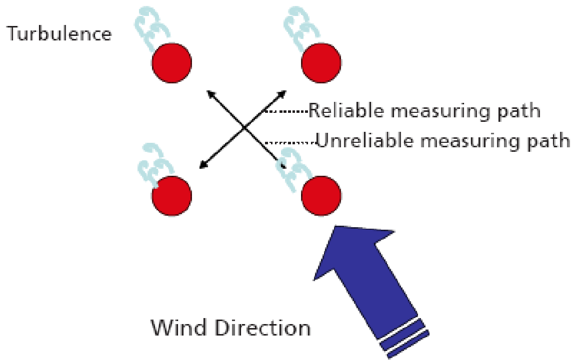

Figure 4.
Orthogonal design.

Calibration of the WSS

The WSS sensor does not require periodic calibration. The physical separation distance between transducers as well as the accuracy of the microprocessor clock determines the sensor accuracy.
The 3 transducer support arms are integrated in the moulded top part of the sensor and keep the separation between the transducers constant over time, and a precision crystal oscillator maintains the accuracy of the microprocessor clock to a high degree relative to the specified sensor accuracy. In combination, this means that when the sensor is calibrated in the production process as described below, it does not need to be calibrated again.

Automated testing and calibration of the WSS in the production line

The sensor under test is placed in a test chamber with controlled environment and absolutely no air movement, and the unit is connected to a PC and powered up.
The test process is controlled by the connected PC and is performed by the PC requesting the WSS to make a series of transmissions. One transducer first transmits a series of bursts to the other 2 transducers, which will receive the burst and store the TOF (time of flight) measurement. Then the same procedure is followed for the other 2 transducers used as a transmitter.
The result is a complete set of measurements recorded in a controlled environment. The data will be processed by the connected PC and a set of "calibration parameters" are calculated and sent to the micro controller in the WSS where it is stored in non-volatile memory (permanently stored). The "calibration parameters" are then used by the WSS micro controller to compensate for the inaccuracy of the physical location of each transducer and the small time delay offset that may be between each of the 3 TX/RX channels (in the electronic circuit).
This automated test process will ensure that the WSS sensor is calibrated.
Finally, a known reference wind flow is introduced in the test chamber to verify that the WSS calibration is correct and that the sensor accuracy is within specifications.

Installation and verification of the WSS

It is important that the installation instruction is followed when the WSS sensor is installed, it must be correctly aligned according to the instructions. If the alignment is properly performed, the wind direction measurement will be within the specification, and the same goes for the wind speed. It should then be verified that the wind direction and speed is presented on the WSDI or WSDI-2 display, if the alignment is performed correctly, no further verification is needed.

After installation verification

If verification of the WSS is required anyhow, it is possible but requires additional equipment.
To verify the data coming from the sensor after installation, the WSS has to be connected to a wind instrument.
The wind direction can be verified by a hand-held wind vane, located in the vicinity of the WSS, but not so close that it will disturb the airflow around the WSS.
The wind speed can be verified by a hand-held wind speed meter (anemometer) also located in the vicinity of the WSS.
Alternatively a second portable mechanical wind system can be used as a reference.
It is important that the hand held devices used for verification is of the same or higher accuracy than the WSS (and that might be difficult to find in a hand-held device).
The wind conditions should also be relatively stable to be able to make a valid verification.