



# Velocity Measurement Accuracy in Partially-Filled Pipes and Channels via the Doppler Method

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## Methods of Velocity Measurement

For manufacturers providing meters or sensors making a velocity measurement in partially-filled pipes and channels, the most common method used to measure velocity is the Doppler method.

Using the Doppler method, a signal is generated from the sensor, which is reflected back to the sensor at a shifted frequency by the moving water or solids/air entrained in the water. The frequency shift is calculated from the received signal, and that shift is proportional to velocity. This method can be used with many types of technology, including ultrasonic, radar, and laser; as well as from both within the water and outside it.

There are also different ways to perform the Doppler method. One method is called continuous Doppler, and the other is called Pulse Doppler. Continuous Doppler means that the meter is always generating and receiving signal via two individual transducers. The standard, submersible ultrasonic sensor used in the Greyline AVFM 6.1 Area-Velocity Flow Meter uses this continuous Doppler method. Pulse Doppler systems generate a signal, then time-gate when the signal is analyzed. These Pulse Doppler systems determine the depth where the velocity measurement took

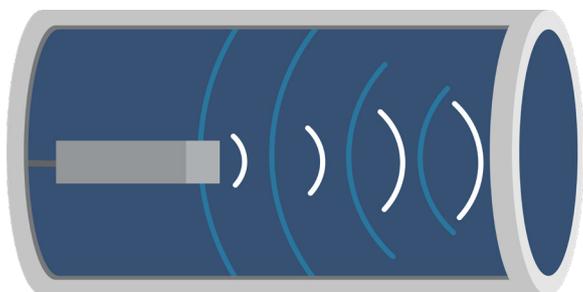
place using this time-gate methodology. Depending on manufacturer implementation, they can also change the timing of the gate so that a velocity profile distribution can be generated using multiple samples.

## Choosing the Right Technology

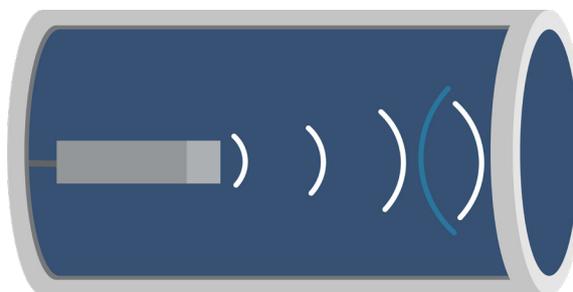
Pulse Doppler meters with velocity profiling capabilities, whether submersible ultrasonic or non-contacting laser, are the newest entries to the area-velocity meter landscape and tout themselves as the most accurate solution no matter the flow conditions where the measurement will take place. These technologies can also be many times more expensive than continuous Doppler meters. *So, is the higher cost worth it?*

The continuous ultrasonic Doppler method used by the AVFM 6.1 has inherent averaging capabilities, even though it is not stated in the name. Ultrasound propagates through water as a wave, forming a cone shape as it travels out and up from the submersible transducer. All of the velocities present within that cone are measured. The signal processing embedded in the meter therefore reports the average velocity. This cone extends up to a height of about 1.3 meters of depth, and as wide as 0.9 meters, encompassing a vast majority of the pipe and channel sizes used in water and wastewater, industrial, irrigation, and environmental applications.

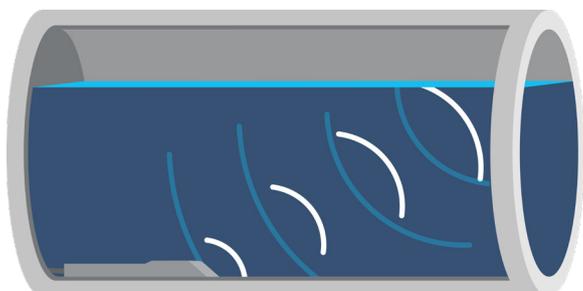
A Pulse Doppler meter will typically determine the time-gate of the echo based on the channel shape and size, and the depth of flow. The depth where the average velocity will occur is calculated with this information using fluid dynamics equations.



Top view of a submersible, continuous Doppler velocity sensor in a pipe. All velocities within the white cone of ultrasound are reflected back to the sensor and averaged together.



Top view of a submersible, Pulse Doppler velocity sensor in a pipe. Only the velocity from the echo received at the determined time-gate is measured.



Side view of a submersible, continuous Doppler velocity sensor in a pipe. All velocities within the white cone of ultrasound are reflected back to the sensor and averaged together.



Side view of a submersible, Pulse Doppler velocity sensor in a pipe. Only the velocity from the echo received at the determined time-gate is measured.

An independent study by the US Department of the Interior titled Laboratory Evaluation of Open Channel Area-Velocity Flow Meters helps shed some light on performance differences in these technologies. In this study, a number of different area-velocity technologies and methods were tested against each other in laboratory settings in a 3 foot rectangular, 18 inch round, and 1.5 foot trapezoidal channels. When comparing the continuous Doppler Greyline AVFM 5.0 used in this study against the profiling Pulse Doppler meters, the average accuracies against the reference flow meter were as follows:

Channel Type & Size	AVFM 5.0 Average Accuracy, %	Nivus PCM Pro Average Accuracy, %	SonTek Argonaut SW Average Accuracy, %	SonTek IQ Average Accuracy, %
3 Foot Rectangular	4.8	-4.5	-11.2	0.51
18 Inch Round	5.2	5.1	-6.3	N/A
1.5 Foot Trapezoidal	8.9	3.7	-14.4	0.3

Table 1 – Reported Accuracy from US Department of Interior Report

If you remove data from velocities less than 1 ft/s, because Doppler velocity uncertainty specifications are typically percent of scale at such low velocities, the average accuracy becomes:

Channel Type & Size	AVFM 5.0 Average Accuracy, %	Nivus PCM Pro Average Accuracy, %	SonTek Argonaut SW Average Accuracy, %	SonTek IQ Average Accuracy, %
3 Foot Rectangular	-0.75	-9.8	-4.3	-6.1
18 Inch Round	5.2	5.1	-6.3	N/A
1.5 Foot Trapezoidal	0.45	-4.4	-15.9	-6.8

Table 2 – Reported Accuracy from US Department of Interior Report, Velocities > 1 ft/s Only

Another point to consider is when flow is fully-developed, meaning the water has a consistent and predictable velocity profile, and there should be no performance difference between any Doppler technology and method used. In the real world, bends, outlets, inlets, changes in level, or any other disturbance will cause the velocity profile to be distorted. This distortion is also unpredictable depending on how much flow there is in the pipe at any given time.

### Conclusions

Given the unpredictability of real-world applications, you need to choose a meter that can handle that variability without the need to reconfigure it when the process changes. The continuous sampling, repeatable, and wide-area averaging capabilities inherent in the AVFM 6.1 make it a superior choice over Pulse Doppler systems. In situations of extremely poor velocity profiles in large channels flowing at less than 1 ft/s, a Pulse Doppler system with the ability to take multiple samples in both the vertical and horizontal direction could have a performance advantage according to the referenced report, but at a significant cost difference (two to three times the price of the AVFM according to the report) and an increase in the processing time between measurements.



Water flow through a culvert. Pulsar pipe dam installed a few feet from the drain side to maintain minimum water level.

### More Information

Greyline AVFM 6.1: <https://pulsarmeasurement.com/avfm-6-1>

US Department of the Interior Report: [https://www.usbr.gov/research/projects/download\\_product.cfm?id=554](https://www.usbr.gov/research/projects/download_product.cfm?id=554)



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