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## Application Note 1000

# Non-Contact Speed Measurement Using Doppler Radar

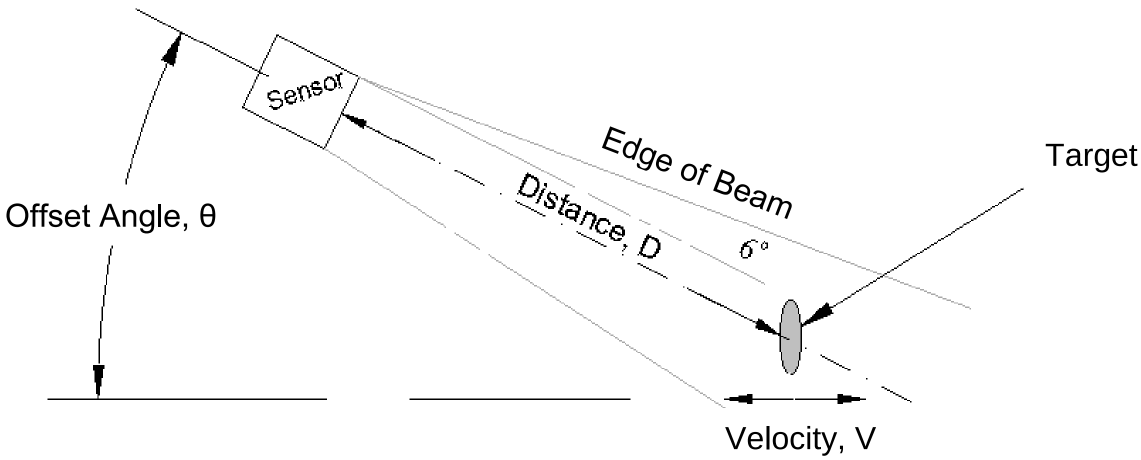


**Figure 1: Example schematic showing the Delta DRS1000 Speed Sensor in use.**

### Doppler Shift Principle

The Delta DRS1000 Speed Sensor is a Doppler radar device that determines a moving object's speed using the Doppler effect, or Doppler shift. According to the principle of the Doppler effect, when a wave reflects off of, or is emitted by, a moving object, the wave's frequency is changed, or shifted. A common example of the Doppler effect can be observed when a car drives past a bystander. To the bystander, the car sounds higher in pitch as it approaches and lower in pitch as it recedes. The Doppler effect is given in Equation 1, where it can be seen that the Doppler shift depends on the velocity of the object and the original wave frequency.

$$F_d = 2V\left(\frac{F_0}{c}\right)\cos(\theta) \qquad (1)$$

The following apply in Equation 1:

$F_d$ = Doppler shift (Hz) $c$ = Speed of light
$V$ = Velocity $F_o$ = Original wave frequency (Hz)
$\theta$ = Offset angle of sensor relative to direction of object motion

The Delta speed sensor uses the Doppler effect to determine the speed of a moving object. The sensor emits a constant-frequency radio wave ($F_0 = 35.5 \pm 0.1\ GHz$). As that radio wave encounters moving objects, part of the wave is reflected back to the speed sensor at a slightly shifted frequency, being shifted by $105.8 \pm 0.3$ Hz for every mph ($65.74 \pm 0.19$ Hz per kph) of the object's velocity. The Delta speed sensor then determines the Doppler shift of the wave and outputs a square wave signal based on that Doppler shift. The frequency of the square wave output is proportional to the object's velocity relative to the sensor. The frequency of the output increases by 100 Hz for every mph (62.1 Hz per kph) of velocity.

It should be noted that the measured velocity is the relative velocity between the object and the sensor- either the sensor or the object, or both, can be in motion.

## Correction for Offset Angle

As can be seen in Equation 1, the Doppler shift is also affected by the offset angle $\theta$ as depicted in Figure 1, or the angle between the sensor's emitted beam and the direction of travel of the moving object. If this angle were zero, then its cosine would be equal to one, and it would have no effect on the Doppler shift. However, for many applications the offset angle $\theta$ is not equal to zero, introducing what is known as cosine error, and it must be accounted for.

If the offset angle $\theta$ to be used could be measured and known exactly, then accounting for it would be a simple matter of measuring the angle and including it in the speed calculation. However, the beam emitted by the Delta speed sensor is approximately cone-shaped as indicated in Figure 1, similar to the beam of light from a flashlight. A cone-shaped beam will encounter a moving object as a roughly elliptical shape, resulting in different values of $\theta$ throughout the beam. This results in an effective offset angle, which is best accounted for through calibration. Methods for correcting for these errors are discussed in Application Note 1001 – Using Non-Contact Speed Sensing to Measure Vehicle Ground Speed, and Application Note 1003 – Distance Applications Using the Non-Contact Speed Sensor.

## Signal Strength and Multiple Targets

The Delta DRS1000 Speed Sensor's signal processing algorithm requires a minimum magnitude of signal before it will start to track the speed of an object, or target. The magnitude, or strength, of a signal is affected by such factors as the speed and size of the object, how reflective the object is, and how close it is to the speed sensor. If the signal from a target is strong enough, the speed sensor will track its speed. This is referred to as "locking on" to the target. It should be noted that the radio waves used by the Delta speed sensor are electromagnetic waves, like visible light but at a different wavelength. Because of this the Delta speed sensor's beam will behave differently than visible light in some cases. Some materials, like certain plastics, are reflective to visible light but can be somewhat transparent to the speed sensor's emitted waves. With other materials, the opposite may be true.

In ordinary use it is possible, and in many cases likely, that the sensor will encounter signals from multiple moving objects at the same time. When "seeing" multiple objects, the sensor locks onto the strongest signal. Careful positioning and alignment of the sensor can be very important when measuring speed. For instance, when using the Delta speed sensor for traffic monitoring it may be important to position the sensor so it only "sees" one lane of traffic, and only one car in that lane at a time.

GMH Engineering is available and willing to assist its customers with determining effective ways to use the Delta DRS1000 Speed Sensor. We are also available to assist in deciding whether or not our sensor is appropriate for your specific applications.

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