AN-026 Speed Accuracy Measurement Using Tuning Forks

One question that comes up with radar speed sensors is how accurate are they and can the speed be verified? The easiest method to confirm the accuracy of the radar sensor is to use a certified tuning fork which is available at a relatively low cost compared to much more expensive RF test equipment. This application note explains the usage of tuning forks to measure the sensor speed accuracy, testing results for the OPS243, and the math behind using a tuning fork. In addition, all OPS24x sensor designs are certified by a police radar certification laboratory and the associated certification documents are provided in Appendix A-C.

Radar Sensor Tuning Forks

Certified tuning forks (Figure 1) are the simplest means of validating the speed accuracy of the radar sensor. They are inexpensive, easy to use, and quick to measure.

Figure 1. 24GHz (K-band) Certified Tuning Forks

For radar speed signs or traffic monitoring, special tuning forks are available for a rated speed. When acquiring or using one of these tuning forks, make sure that they are designed for the frequency of operation of the radar sensor. OPS24x radar sensors operate at 24.0-24.25GHz. Look for vehicle speed tuning forks which are designed for the K-band, typically designed for operation at 24.15GHz. For accurate readings, the OPS24x can be tuned via the API to operate near 24.15GHz. The default frequency settings for the OPS241-A, OPS242-A, and OPS243-A is 24.125GHz. The difference from 24.15GHz provides an error of 1-4Hz depending on the speed. The API command for the OPS241-A, OPS242-A, and OPS243-A frequency control is the T=*n* command with *n*=0 the default setting. Increments of *n* shift the frequency of operation in 40MHz steps. The OPS243-C uses a hardware PLL circuit which locks the frequency to within 1MHz. Vehicle tuning forks are also available in the X-band (8-12GHz) and Ka-band (26.5-40GHz) frequencies. These should not be used when verifying the OPS24x speed.

Alternatively, any other tuning fork with a known frequency of operation can be used. Math provided to convert from frequency to expected speed reading is provided below. Alternatively, the OPS24x API can be set to output the detected frequency (UH command) which can be compared directly to the tuning fork frequency.

Testing with a Tuning Fork

Testing with a tuning fork is a simple process. First, make sure the sensor is set to output the speed units desired. If a vehicle speed tuning fork is used, for example a 35-mph tuning fork, set the output units to mph with the US API command (UK if setting for kmh, UH for frequency in Hz). You may want to adjust the number of digits reported as well (F*n* API command, *n* = number of digits).

When your output settings are configured as desired, simply tap the tuning fork on a hard surface and hold it near the sensor transmit or receive antenna, ideally 5-10 cm (2-4 in.) above the sensor. A stream of speed reports near the tuning fork speed will be reported as shown in Figure 2.

Higher frequency (higher speed) tuning forks become more challenging for the sensor to pick up due to the slight motion of the tuning fork. From practical experience, the OPS24x can detect a 65-mph tuning fork (2,338 Hz) but sometimes the signal magnitude threshold needs to be adjusted down to a value of 10 (M>10 command) and/or output the top 3 speed readings (O3 command).

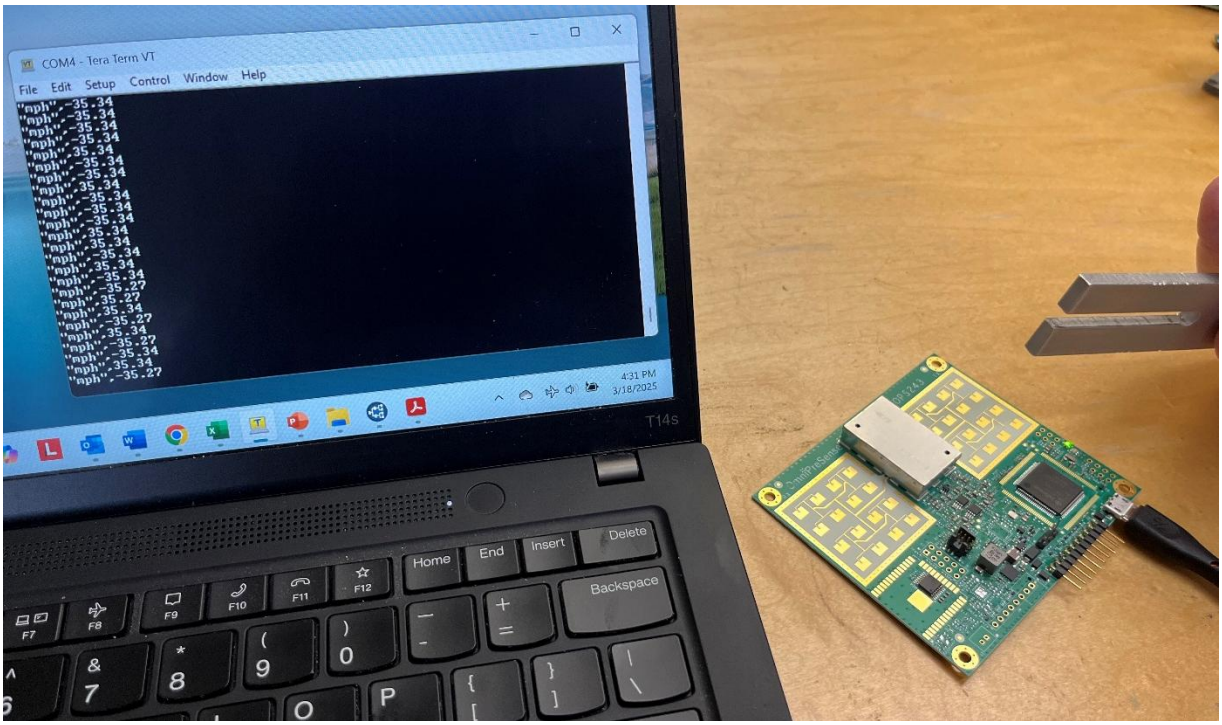

Figure 2. Tuning Fork Test Position and Speed Reports

In Figure 2, the speed reports are presented using a Teraterm terminal window. As seen, the speed reports are either 35.27 or 35.34-mph for a 35-mph tuning fork. This results in an average speed accuracy of within 0.9% of the tuning fork rated speed value. Both negative and positive speeds are reported. The + and - sign can be ignored as the sensor is picking up the tuning fork either moving towards or away from it. When calculating the accuracy, use the absolute value of the reported speed values.

Via the API, the sensor speed resolution can be enhanced to provide additional resolution. The default speed resolution of the OPS24x is 0.0607 m/s or 0.1358-mph (0.218-kmh). Adjustments to the sample rate, sample size, and FFT size can make the resolution even finer. In general, slower sample rates, larger sample sizes, and larger FFT size improve the speed resolution. For example, a typical vehicle speed detection setting is:

- Sample Size: 1024 (S> command, default)
- Sample Rate: 20ksps (S2 command)
- FFT Size: 4096 (X4 command, do after changing sample size and sample rate)
- Speed Resolution: 0.0303 m/s (0.0679-mph or 0.1093-kmh)

Radar Tuning Fork Math

The math behind the frequency and speed measurements is straightforward. The primary equation is:

Equation 1. Radar Speed Equation $$v = \frac{\Delta fc}{2f_O}$$

With the variables representing:

v = speed in m/s

Δf = Doppler frequency shift measured by the sensor

c = speed of light

f_O = operating frequency (24.125GHz)

As an example, a Doppler shift frequency of 2,518Hz provides a speed reading of 35-mph. This equation can be rewritten to determine the expected speed for a given frequency tuning fork. A 1,024 tuning fork calculates to 28.5-mph (45.8 kmh or 12.72 m/s). Table 1 provides a convenient look-up table of frequencies and speeds.

Table 1. Typical Frequency and Speeds

Frequency (Hz)	Speed (m/s)	Speed (kmh)	Speed (mph)
128	0.80	2.9	1.8
256	1.59	5.7	3.6
512	3.18	11.5	7.1
1024	6.36	22.9	14.2
1439	8.94	32.2	20.0
1799	11.18	40.2	25.0
2048	12.72	45.8	28.5
2518	15.65	56.3	35.0
3238	20.12	72.4	45.0
3957	24.59	88.5	55.0
4096	25.45	91.6	56.9
4677	29.06	104.6	65.0
5396	33.53	120.7	75.0

The measured FFT output from a 2,048Hz tuning fork is shown in Figure 3. As can be seen, a very strong peak signal is present near 2,048Hz. The actual peak is at 2,056 Hz, 8 Hz off from the target or less than 0.4% difference from the desired frequency.

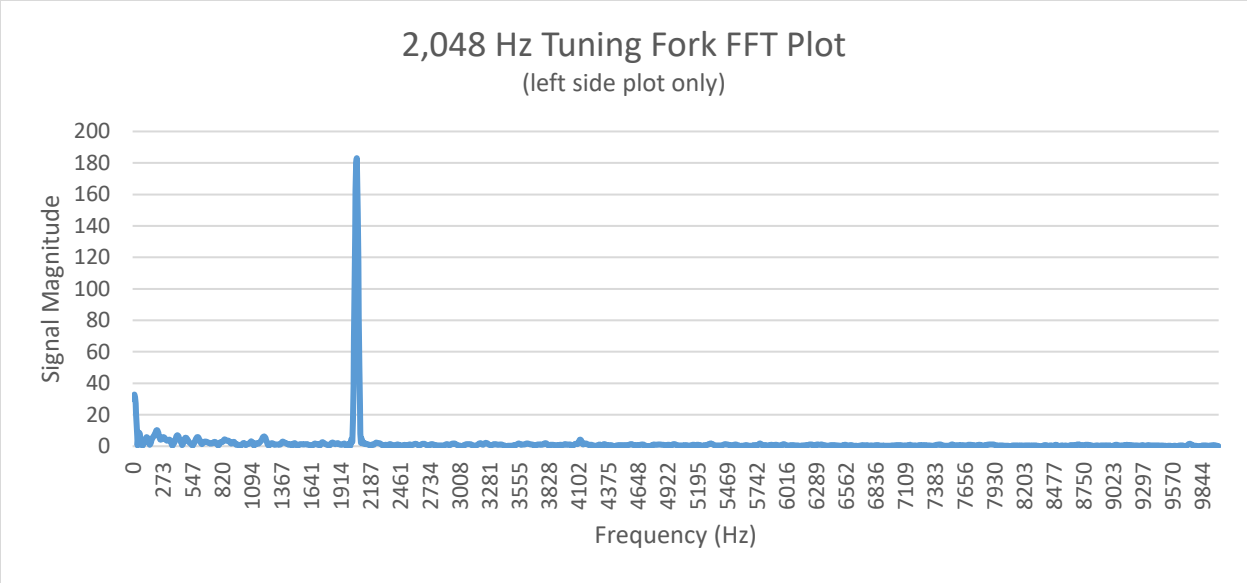

Figure 3. Reported FFT of 2,048 Tuning Fork (left side plot only)

Appendix A – OPS242-A Police Certification

SOUTHERN CALIFORNIA RADAR/LASER CERTIFICATION LABORATORY

P.O. Box 1177
Pine Valley, CA 91962

I certify that the OmniPreSense Radar module, model OPS-242, Serial Number 260570010 was tested on July 24, 2018 and was calibrated to be within the Industry/Manufacturers specifications for accuracy.

- Unit meets or exceeds the NHTSA standards for accuracy.
- Unit meets or exceeds the standards set forth in cvc 40802().

Test Results

Test	Min	Max	Read	Pass
Visual/Function	-	-	-	Yes
Tuning Fork Frequency s/n N/A	-.5%	+.5%		
Radar Device Tuning Fork	-1MPH	+1MPH	N/A	
Microwave Frequency – K-Band 24.125	-150MHz	+150MHz	24.1243GHz 24.1250GHz 24.1271GHz 24.1262GHz	Yes
Radiated Output Power Variation	-1.5dB	+1.5dB	+.04	Yes
Antenna Horizontal Bandwidth K-Band	-	-	66°	Yes
Low Voltage Supply	-	2.8V	2.6	Yes
Accuracy-Stationary Mode REC	2MPH	+1MPH	0	Yes
Accuracy-Stationary Mode APR	2MPH	+1MPH	0	Yes
Target Channel Sensitivity	<10dB (35-90 MPH)		4.3dB (avg.)	Yes
Antenna Near Field Maximum Power Density		0dBm/cm²	-27.3dBm/cm² -31.8dBm/cm² -26.2dBm/cm² -29.5dBm/cm²	Yes
25 MPH	-2MPH	+1MPH	25 MPH	Yes
50 MPH	2MPH	+1MPH	50 MPH	Yes
130 MPH	-2MPH	+1MPH	130 MPH	Yes

By: _____ Date: July 24, 2018
William F. Dunable, MS/CIS FCC Lic. # PG-11SD-2354

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Appendix B – OPS243-A Police Certification

SOUTHERN CALIFORNIA RADAR/LASER
CERTIFICATION LABORATORY
P.O. Box 1177
Pine Valley, CA 91962

I certify that the OmniPreSense Radar module, model OPS-243-A, Serial Number 274040006 was tested on June 15, 2019 and was calibrated to be within the Industry/Manufacturers specifications for accuracy.

- Unit meets or exceeds the NHTSA standards for accuracy.
- Unit meets or exceeds the standards set forth in cvc 40802().

Test Results

Test	Min	Max	Read	Pass
Visual/Function	-	-		Yes
Tuning Fork Frequency s/n N/A	-.5%	+.5%		-
Radar Device Tuning Fork	-1MPH	+1MPH	N/A	-
Microwave Frequency – K-Band 24.125	-150MHz	+150MHz	24.121GHz to 24.125GHz	Yes
Radiated Output Power Variation	-1.5dB	+1.5dB	+.051	Yes
Antenna Horizontal Bandwidth K Band	-	-	62°	Yes
Low Voltage Supply	-	2.8V	2.5	Yes
Accuracy-Stationary Mode REC	-2MPH	+1MPH	0	Yes
Accuracy-Stationary Mode ALK	-2MPH	+1MPH	0	Yes
Target: Channel Sensitivity	<10dB (35-90 MPH)		2.6dB	Yes
Antenna Near Field Maximum Power Density		0dBm/cm²	-32.34dBm/cm²	Yes
25 MPH	-2MPH	+1MPH	25 MPH	Yes
50 MPH	-2MPH	+1MPH	50 MPH	Yes
130 MPH	-2MPH	+1MPH	130 MPH	Yes

By: _____ Date: June 15, 2019
William F. Dunable, MS/CIS FCC Lic. # PG-11SD-2354

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Appendix C – OPS243-C Police Certification

SOUTHERN CALIFORNIA RADAR/LASER
CERTIFICATION LABORATORY

P.O. Box 1177
Pine Valley, CA 91962

I certify that the OmniPreSense Radar module, model OPS-243, Serial Number 282890034 was tested on October 31, 2019 and was calibrated to be within the Industry/Manufacturers specifications for accuracy.

- Unit meets or exceeds the NHTSA standards for accuracy.
- Unit meets or exceeds the standards set forth in cvc 40802().

Test Results

Test	Min	Max	Read	Pass
Visual/Function	-	-	-	Yes
Tuning Fork Frequency s/n N/A	-.5%	+.5%		-
Radar Device Tuning Fork	-1MPH	+1MPH	N/A	-
Microwave Frequency – K-Band 24.125	-150MHz	+150MHz	24.123GHz to 24.125GHz	Yes
Radiated Output Power Variation	-1.5dB	+1.5dB	+.051	Yes
Antenna Horizontal Bandwidth K-Band	-	-	62°	Yes
Low Voltage Supply	-	2.8V	2.5	Yes
Accuracy-Stationary Mode REC	-2MPH	+1MPH	0	Yes
Accuracy-Stationary Mode APR	-2MPH	+1MPH	0	Yes
Target Channel Sensitivity	<10dB (35-90 MPH)		2.6dB	Yes
Antenna Near Field Maximum Power Density		0dBm/cm²	-37.16dBm/cm²	Yes
25 MPH	-2MPH	+1MPH	25 MPH	Yes
50 MPH	-2MPH	+1MPH	50 MPH	Yes
130 MPH	-2MPH	+1MPH	130 MPH	Yes

By: _____ Date: October 31, 2019
William F. Dunable, MS/CIS FCC Lic. # PG-11SD-2354

This unit has passed all applicable tests set forth by the NHTSA and IACP. The tests passed all tests per the manufacturers test procedure and results. I hereby certify the unit as noted and tested within the environmental parameters set forth by all applicable agencies.

William F. Dunable, MS/CIS FCC Lic. # PG-11SD-2354

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Revision History

Version	Date	Description
A	March 19, 2025	Initial release.