AN-029 OPS24x for Sports Applications

In many sports, it's of interest to know the speed of the ball or object used in the sport. The OPS24x radar sensor provides a very good means to accurately measure the speed of the object and with additional processing, may provide other parameters to measure performance. These parameters may include spin or direction of movement. In addition, capturing multi-speed reports allows detection of objects used to hit the ball (ex. club in golf). The flexible API of the OPS24x can be tuned for very fast speeds of these objects, up to 210 mph (93.9 m/s). This application note provides recommendations for API tuning for various sports with additional guidance towards best mounting location. While both OPS242-A and OPS243-A support the features discussed below, OPS243-A is the recommended sensor solution given its further detection distance and ability to pick up small, weak reflective objects. Special API modes such as Rolling Buffer are only available on OPS243-A.

Sports Ball Reflectivity

The ability of short-range radar to detect objects like balls depends on the size, shape, and material of the object. In general, larger, flatter, and harder materials reflect better and can be detected farther away. But in sports, many of the objects are small, round, and made of soft material. A summary of objects used in sports and their relative reflectivity is shown in Table *1*.

Table 1. Sport Object Reflectivity

Object (Ball)	Max Speed	Size (Diameter)	Reflectivity
Baseball	108 mph (pitch) 118 mph (exit)	7.6 cm	Medium
Basketball	48 mph	75 cm	Medium
Cricket	100 mph	7.2 cm	High
Football (American)	63 mph (thrown) 80 mph (kicked)	17x28 cm	Low
Futbol (Soccer)	80 mph	22 cm	Low
Golf	211 mph	4.3 cm	High
Hockey	108 mph	0.4 x 1.2 cm	High
Rugby	85 mph (kicked)	19x29 cm	Low
Tennis	160 mph	6.7 cm	Very Low
Volleyball	110 mph	20.7 cm	Low
Water Polo	55 mph	22.6 cm	Medium

Sports Ball Detection API Configuration

For many sports, the main object is determining the speed of the ball used in the sport. Typically, the faster the speed, the better the performance of the player or better chance at scoring. When using a short-range radar like OPS24x, the main goal is to capture as much speed data about object movement as

possible. When a lot of speed data is available, further processing provides additional information about the movement of the ball. For example, in golf, ball speed, spin, and launch angle together are part of the equations for the flight of the ball, proving calculated Carry and Apex values.

The key API configurations are set to maximize as much information about the flight of the ball as possible. The changes include:

- Sample rate (S2 or S=30 commands)
    - Increase to 20ksps or 30ksps from default 10ksps
    - Determines max possible detected speed
- Sample size (S<, S[, S(commands)
    - Decrease to 512/256/128 depending on application
    - Increases report rate
- FFT size (X2, X4, X8, X=16, X=32 commands)
    - Increase multiple of FFT to sample size with X2/X4/X8/X=16/X=32
    - Improves speed resolution, set this after changing sample size
- Timestamp – set to process incremental speed reports
- Multi-object Speed Reporting (O2 or O3 commands)
    - Report speed of ball and object used to hit the ball
    - Calculating values such as Smash Factor in golf
- Peak Detect (K+ command) – helps report single speed per object detected
- Magnitude Threshold adjust (M>15, M>10 commands) – increase sensitivity of hard to detect objects at farther distances

Mounting Position

The mounting position of the sensor relative to the ball travel is very important. This affects both the ability of the sensor to detect the ball, the maximum distance of detection, and the accuracy of the speed reported. Ideally, the ball should be coming straight towards or away from the sensor.

OPS243 has a field of view that is 20° wide in the horizontal and 24° in the vertical while OPS242 has a 76°-degree field of view in both the horizontal and vertical direction. To visualize the sensor field of view, think of a cone extending out from the sensor which widens as it gets farther away from the sensor (Figure 1). The ball should pass through the sensor field of view and for best detection range, should be as close to the center line of the field of view cone as possible.

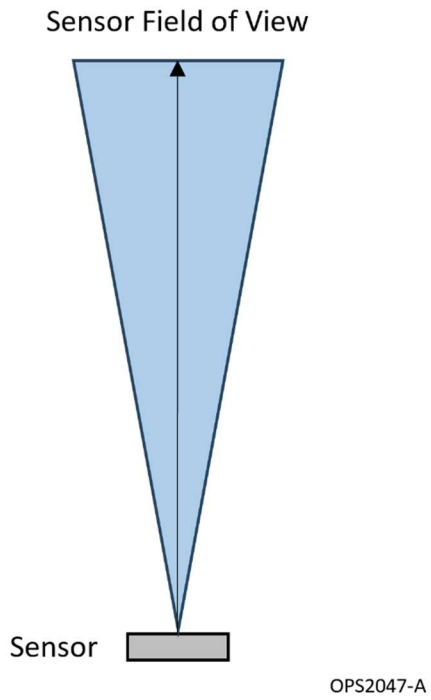

Figure 1. OPS24x Sensor Field of View

A ball which passes off to the side of the cone introduces a cosine error in the speed reported by the sensor. The sensor will report the actual speed reduced by the cosine of the angle the ball makes with the sensor. See AN-11 Cosine Error for further discussion and the calculations behind the cosine error.

Table 2. Field of View Measurements

Detection Distance	OPS242				OPS243			
	Horiz. (m)	Horiz. (ft.)	Vert. (m)	Vert. (ft.)	Horiz. (m)	Horiz (ft.)	Vert. (m)	Vert. (ft.)
1m/3.3 ft.	1.6	5.1	1.6	5.1	0.4	1.2	0.4	1.2
1.5m/5.0 ft.	2.3	7.7	2.3	7.7	0.5	1.7	0.5	1.7
3.1m/10.0 ft	4.8	15.9	4.8	15.9	1.1	3.6	1.1	3.6
5.0m/16.4 ft	7.8	25.6	7.8	25.6	1.8	5.8	1.8	5.8
6.1m/20.0 ft.	9.5	31.3	9.5	31.3	2.2	7.1	2.2	7.1
10m/32.8 ft.	15.6	51.3	15.6	51.3	3.5	11.6	3.5	11.6

Baseball

Baseball statistics have always been an important method of determining how good a team or player is. The velocity of the pitched ball and more recently ball exit velocity are key statistics. The recommended API configurations for baseball are listed in

. Given the high speed of the ball, over 100 mph possible, a very high sample rate is used. Optionally, capturing two speed reports can provide bat speed.

Table 3. Baseball Recommended API Settings

API Setting	Value	API Command	Notes
Sample Rate	30ksps	S=30 (enter)	Max detectable speed 210mph
Sample Size	128	S(	Increased report rate
FFT Size	4096	X=32	Increase resolution (0.1 mph)
Units	mph	US	
Peak Detect	-	K+	Isolate speed detections
Multi-object	-	O2	Optional
Speed Filter	>5 mph	R>5 (enter)	Remove movement of batter
Magnitude Threshold	10 or 15	M> 10 (enter)	Increase detect distance

Baseballs are relatively small objects to detect and are not very reflective to the OPS24x given their leather material. For this reason, reduce the signal magnitude threshold to either 15 or 10 to help increase sensitivity and detection distance.

The mounting position of the sensor is very important and challenging with baseball. Ideally the sensor would want to be located where the catcher or umpire is located. This is not physically possible so mounting the sensor as close as possible to this position. Figure 2 shows an example of the mount location when a catcher is present. Keeping the sensor close to the line of the ball path and angling the sensor slightly towards the balls flight helps minimize cosine error. If using a batting cage, the sensor can be mounted outside of the screen/net.

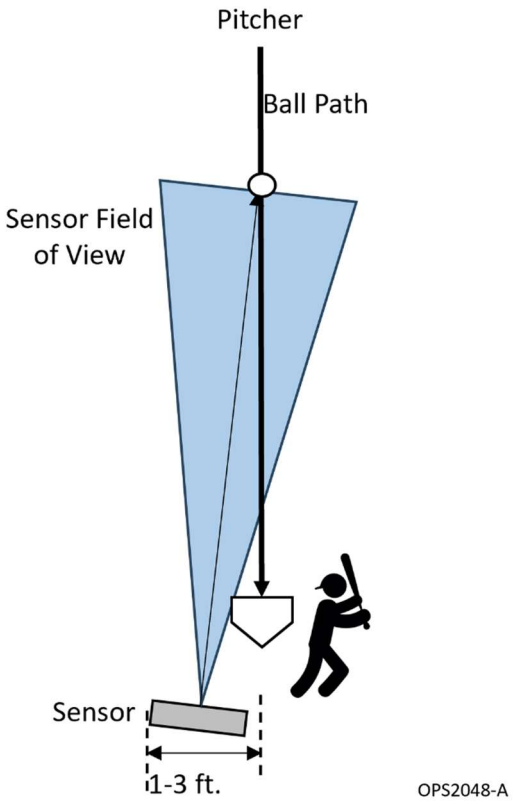

Figure 2. Baseball Sensor Mounting Position with Batter

The baseball will show up as a positive (inbound) speed initially and if hit, will show a sudden reversal to a negative speed. The max negative speed recorded is the exit velocity of the ball.

Multi-object detection can provide the speed of the ball and the bat as it is swung. The bat, being closer and solid, more reflective object, will provide a solid set of speed readings. Given the bat comes from the edge of the sensor field of view, swept into the sensor field of view, and then moves out, its speed will show a heavy cosine error. This will be represented by a speed reading that changes from a low value to a max value and back to a low value over its reporting. The max or peak speed should be considered the true value of the bat as that's when it's most in line with the sensor field of view.

Basketball

Basketball speed is generally not captured but is possible. The ball is of decent size and required detection distance is not that far (<47 ft./14 m). A possible mounting location above the backboard with the sensor angled down slightly. Given the wide angle a shot can come from, the OPS242-A with its 76° field of view may be a good choice.

Cricket

Cricket balls are slightly smaller than baseballs but are heavier and provide similar mounting position issues. The same API configuration settings found in Table *3* can be used for cricket with adjustments to kmh using the UK API command. The mounting of the sensor is more like golf, being positioned a distance behind the stumps. With the sensor 2 m/6.6 ft. behind the stumps, the sensor field of view is 0.7 m/2.3 ft. wide and 0.9 m/3.0 ft. tall. This should be wide enough to pick up the ball.

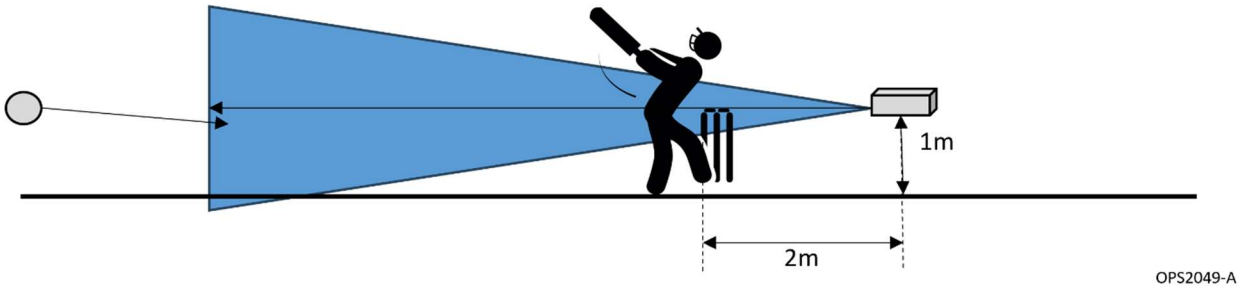

Figure 3. Cricket Sensor Mounting Position

Football (American)

Football provides a larger ball for detection but soft leather material which is not as reflective. The speed from a pass or kick can be measured by mounting the sensor behind the thrower or kicker. The recommended API configurations are shown in Table 4.

Table 4. American Football Recommended API Settings

API Setting	Value	API Command	Notes
Sample Rate	20ksps	S2 (enter)	Max detectable speed 138mph
Sample Size	128	S(	Increased report rate
FFT Size	4096	X=32	Increase resolution (0.1 mph)
Units	mph	US	
Speed Filter	>5 mph	R>5 (enter)	Remove movement of thrower/kicker
Magnitude Threshold	10 or 15	M> 10 (enter)	Increase detect distance

Football (Soccer)

Football/Soccer provides another ball of decent size but softer material providing and medium detection distance. The ball still can be detected at least 5-10m out. OPS242-A provides an interesting option as its wider field of view can cover the full net opening depending on its placement behind the net. Test data shows detection range of at least 6m. It's also possible to see the kicker leg speed and when the ball hits the back net.

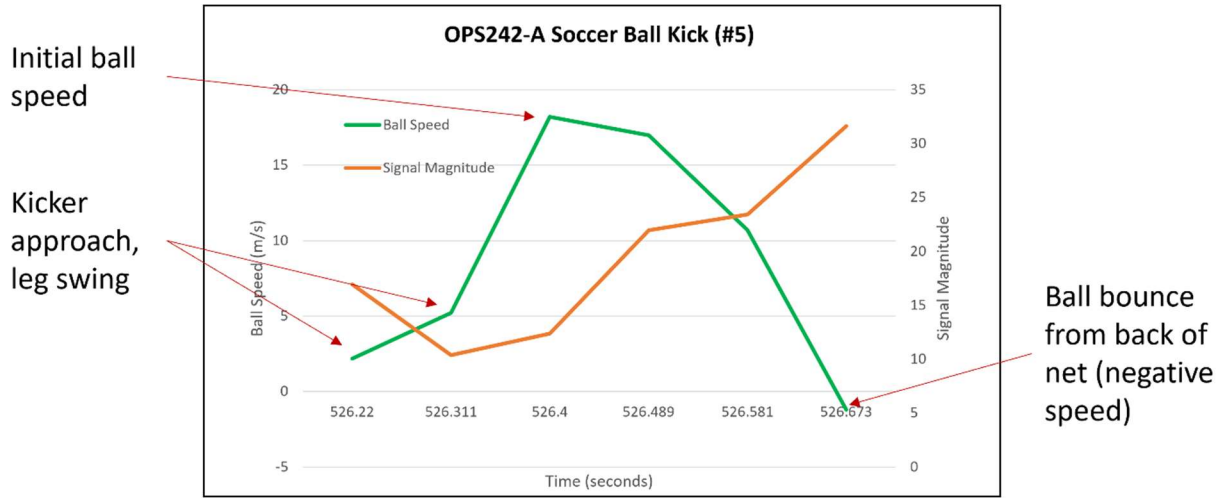

Figure 4. OPS242-A Football/Soccer Detection

Table 5. Football/Soccer Recommended API Settings

API Setting	Value	API Command	Notes
Sample Rate	20ksps	S2 (enter)	Max detectable speed 138mph
Sample Size	128	S(	Increased report rate
FFT Size	4096	X=32	Increase resolution (0.1 mph)
Units	mph or kmh	US or UK	
Speed Filter	>2 mph or >3 kmh	R>2 (enter) or R>3	Remove noise, detect kicker movement
Magnitude Threshold	10 or 15	M> 10 (enter)	Increase detect distance

Golf

Golf provides an interesting challenge due to its extremely small size and very high speed. The ball is typically the only object moving so fast which makes it easier to detect. Fortunately, the ball is a hard plastic which provides detections distances of 5-10m. The sensor is typically placed 2-3m (6-9 ft.) behind the ball facing the direction of travel.

The configuration settings to detect a golf ball need to cover upwards of 210 mph (338 kmh). This requires a very high report and sample rate. To achieve a high report rate, use a lower sample size, 128 samples (S(command). However, this reduces speed resolution. To compensate, use a higher FFT size, 4096, with the S>32 (enter) API command. This provides a speed resolution of 0.1 mph (0.2 kmh). Increase the sample rate to 30ksps (S=30 enter) to achieve a max detectable speed of 209 mph (336 kmh). This combination can provide a report rate near 200Hz (5ms).

The benefit a lot of speed reports is the ability to do further analysis, providing additional information about the golf ball movement. If the time before the ball is hit is captured, it's possible to also pick up the

club speed (Figure 5). With this and the ball speed, the smash factor can be calculated (typically 1.0-1.50). Further analysis of the ball speed reports may provide details of the ball spin.

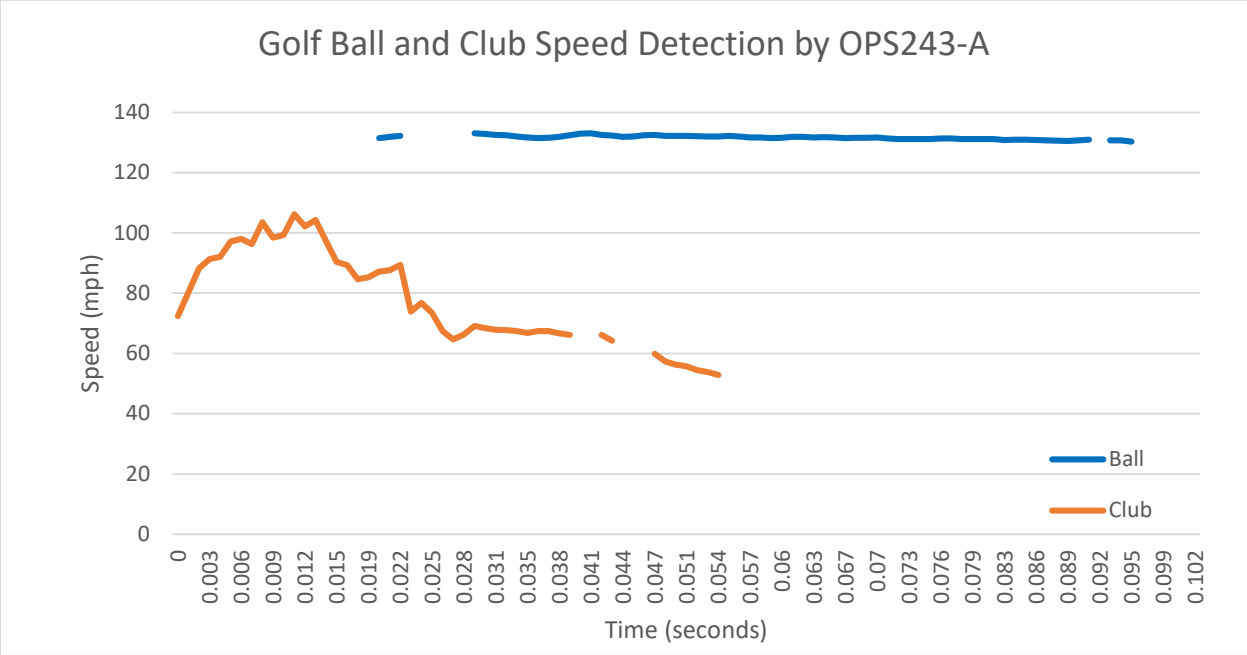

Figure 5. Typical Golf Ball Data

A new feature available in OPS243-A is the Rolling Buffer feature. This helps capture very high-speed events like a golf ball hit. An adjustable trigger allows picking up the early club swing data. Rolling Buffer mode is described more thoroughly in AN-27 application note.

The OpenFlight open-source project provides reference code for a golf ball launch monitor using the OPS243-A. Details of the project can be found on their GitHub site here.

Table 6. Golf Recommended API Settings

API Setting	Value	API Command	Notes
Sample Rate	30ksps	S=30 (enter)	Max detectable speed 209mph
Sample Size	128	S(	Increased report rate
FFT Size	4096	X=32	Increase resolution (0.1 mph)
Units	mph	US	
Speed Filter	>10 mph	R>10 (enter)	Remove slower club movement
Magnitude Threshold	10 or 15	M> 10 (enter)	Increase detect distance
Multi-Speed	-	O2	Provides top 2 speeds captured, ball and club
Peak Detect	-	K+	Focuses multi-speed reports

Hockey

Hockey provides a small, hard object like golf at very high speed (up to 110 mph) and a net like soccer. Placement of the sensor behind the net can easily cover the full net opening. Expected detection distance is similar to golf, 5-10m away, if not better due to the pucks larger size. The same configuration setting (Table 6)used for golf may be used for hockey.

Rugby

Rugby provides a ball similar in size to American football but slightly larger and its material is more reflective. The same API configuration (Table *4*) can be used for Rugby as American Football. Mounting position provides additional challenges but may provide usefulness in training or practices.

Tennis

A tennis ball is a challenging object to detect for radar due to its size and material. The fuzzy, rubbery material is not very reflective to radar, so detection distances are not very far. Placement of the sensor also provides challenges. Serve speed is a key measurement, and the sensor needs to be placed behind the hitter (Figure 6) with serve line to back walls distances of 10-15m (32-50 ft.). The API configurations used with Baseball (Table *3*) can be used for tennis. Due to the weak reflective ball, make sure to adjust the signal magnitude lower.

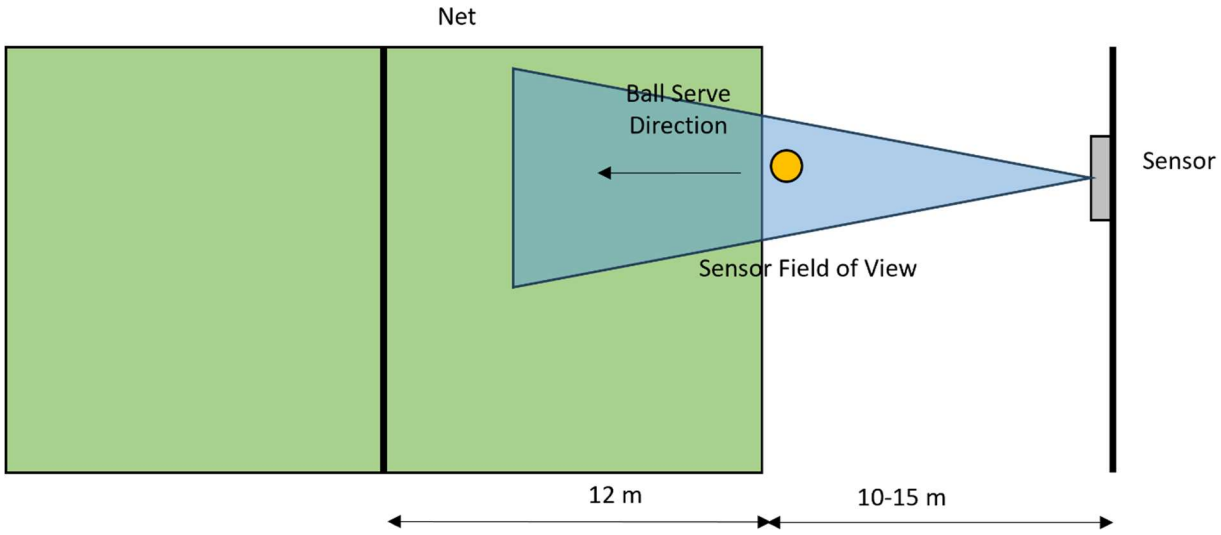

Figure 6. Tennis Serve Mount Position

Track and Field

Track and Field has many events requiring different requirements. Fortunately, most of them are related to detecting people's speed. People are larger objects although not that reflective. OPS243 can detect people up to 10-15m (32-50 ft.) away. The key is to mount the sensor focusing on the torso of the person which provides a flatter, more reflective surface. People are not as fast as sports balls so top speed is easier to measure and speed resolution may be more important. The API configuration settings in Table 7 provide speed resolution of 0.03 m/s and a very fast report rate near 100Hz (10ms). The resolution can be reduced further using the default 10ksps at the expense of a slower report rate.

If desired, it may be possible to capture the speed of the hands/arms and legs separate from the torso (micro-Doppler). The hands/arms have a motion both forward and backwards which is easy to separate from the forward motion of the torso.

Table 7. Track & Field Recommended API Settings

API Setting	Value	API Command	Notes
Sample Rate	20ksps	S=20 (enter)	Max detectable speed 138mph
Sample Size	128	S(	Increased report rate
FFT Size	4096	X=32	Increase resolution (0.1 mph)
Units	m/s	UM	
Speed Filter	0 mph	R>0 (enter)	Default setting
Magnitude Threshold	10 or 15	M> 10 (enter)	Increase detect distance
Multi-Speed	-	O3	If desired to detect arms or legs
Peak Detect	-	K+	Focuses multi-speed reports

Volleyball

Volleyball provides similar mounting position challenges as tennis but at least uses a ball like a football/soccer making detection easier. The API configurations used with Baseball (Table 3) can be used for volleyball.

Water Polo

Water Polo, like Volleyball, is a ball of decent size and reflectivity while mounting position is similar to hockey. The ball speed is not as fast and the API configuration used with Baseball (Table 3) can be used.

Revision History

Version	Date	Description
A	June 21, 2026	Initial release.