INSTRUCTIONS FOR NFSC tour SPEED MEASURING SYSTEM

The NFSC tour Speed measuring system is designed specifically for accurately measuring the speed of tennis serves on the tennis court. The system is intended for permanent installation, and includes weather resistant Radar units for outdoor installations. The system is configurable from 1 to 4 radar units to provide tennis facilities a low cost entry into a speed measuring and display system, with easy upgrade to a professional full court coverage system. By strategically locating the radar units on the court, ball speed estimates can be accurate to within 1 MPH of the actual ball speed. To accomplish this accuracy, it is important to follow the mounting instructions, with special attention to the location (height and distance from center line) of each radar unit. The objective is to mount each radar unit so it is in a straight line with the ball travel for each serve position on the tennis court. The radar unit positions described in these instructions are optimized for serve positions, and provide for accurate speed measurements for the serve. Ball flight paths that are "off line" with the line of the radar unit will be displayed at a slower speed than actual ball speed by the cosine of the angle.
The speed measuring system is available for use with either 2 or 4 radar units. The two-radar unit system is typically set up at one end of the court for competitive fast serve events. The 4-unit system allows for 2 additional radar units to connect to the display, so both ends of the court could be used to accurately measure serve speeds. The 2 radar unit system can alternatively be installed by centering one Radar unit on the centerline of the court at each end, and positioning the height per these instructions.
The NFCS display has three 8" tall digits, is designed for very wide viewing angles, typical visibility is up to 200 feet away with 15 degree side view.

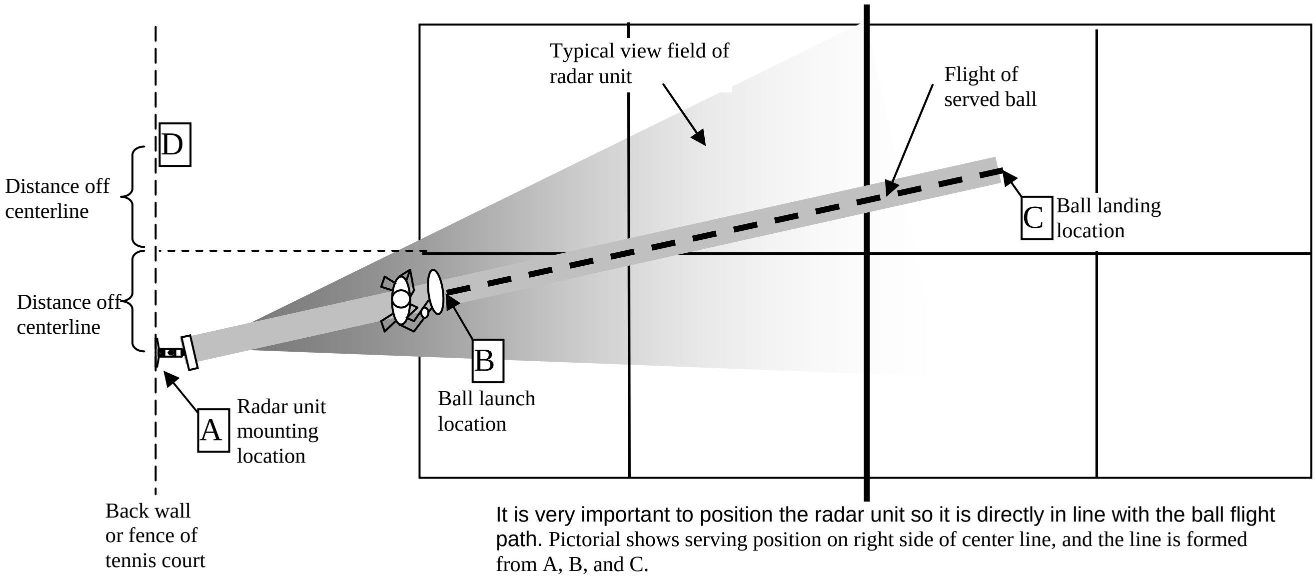
GENERAL: When connecting multiple radar units only the highest speed will be displayed.
Both the mounting height and mounting distance from the centerline of the tennis court are important to assure optimum accuracy. Because the location of the back wall or fence at the installation varies from court to court it is necessary to determine the mounting location based on the intended line of the ball flight. Figure 1 shows the method to determine the optimal distance from the centerline, and Figure 2 shows how to determine the mounting height. Table 1 provides some typical distance to back fence, distance from centerline and height measurements.

DETERMINE THE DISTANCE FROM CENTERLINE
Refer to figure 1, top view of tennis court. The points A (radar unit), B (ball launch point), and C (ball landing point) form a straight line. Position A is the optimal distance from the centerline for a serve from the right side of the centerline. Once this distance from the centerline is determined, the same distance would apply for a radar unit location for a server on the left side of centerline, and the second radar unit would be installed at point D.
For a 4-Radar installation, if the court is symmetrical (i.e. back walls at both ends of the court are the same distance from the net), then this distance from the centerline would also apply for the location of radar units on the RIGHT side of the court. If the court is not symmetrical, then the same method to determine the optimal distance from the centerline for the RIGHT side of the court would apply.

DETERMINE THE HEIGHT
Refer to Figure 2, side view of tennis court. The points 1 (radar unit), 2 (ball launch point), and 3 (ball landing point) form a straight line. Position 1 is the optimal mounting height for both radar units at the LEFT end of the court. If the court is symmetrical (i.e. back walls at both ends of the court are the same distance from the net), then this height would also apply for the height location for radar units on the RIGHT side of the court. If the court is not symmetrical, then the same method to determine the optimal height would apply.

It may be necessary to attach a brace or other construction to the fence (for outdoors courts) or back wall or ceiling structure (for indoor courts) if the specific court does not have a permanent structure at the desired location. NOTE: the location shown provides for optimum accuracy but is not a requirement of the installation; however the registered ball speed will be less than the actual ball speed by the cosine of the angle between actual ball travel and the optimal line at the point where the speed is registered. Figure 3 illustrates a cosine angle and the reduction in registered speed for an installation where the optimal mounting height could not be achieved.

FIGURE 1 Court view from top



It is very important to position the radar unit so it is directly in line with the ball flight path. Pictorial shows serving position on right side of center line, and the line is formed from A, B, and C.

Figure 2 side view of court

It is very important to position the radar unit so it is directly in line with the ball flight path. Pictorial shows serving position on right side of center line, and the line is formed from 1, 2, and 3..

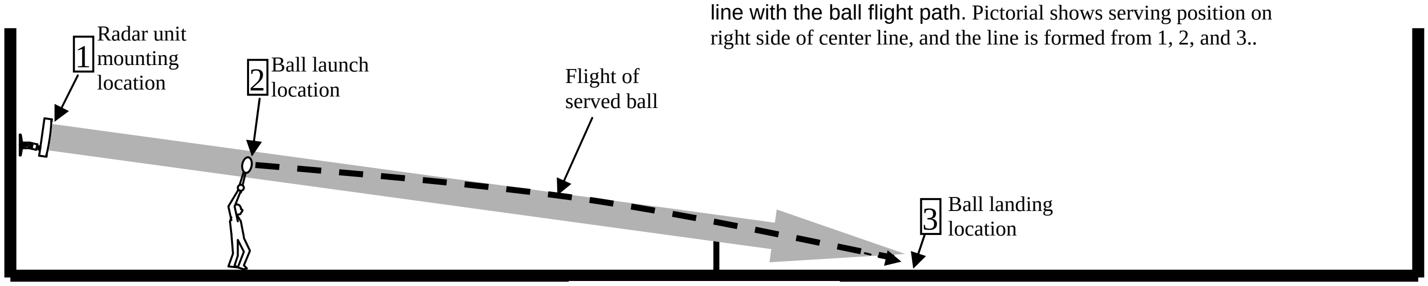
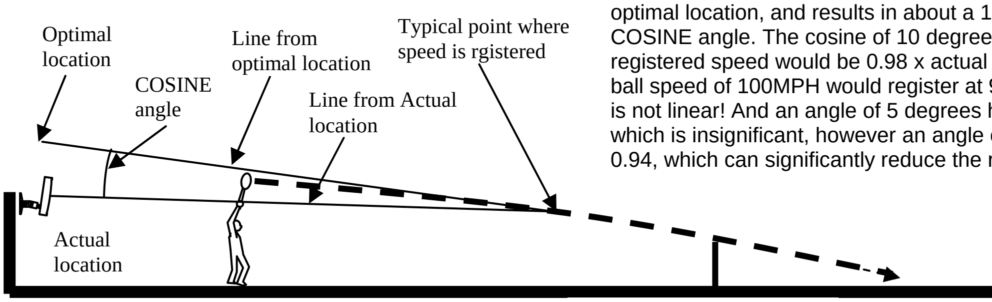


Figure 3 cosine error



In this case, the actual mounting location is slightly lower than the optimal location, and results in about a 10 degree angle, called the COSINE angle. The cosine of 10 degrees is 0.98, and the registered speed would be 0.98 x actual ball speed. So an actual ball speed of 100MPH would register at 98MPH. The COSINE error is not linear! And an angle of 5 degrees has a cosine of 0.996, which is insignificant, however an angle of 20 deg has a cosine of 0.94, which can significantly reduce the registered speed.

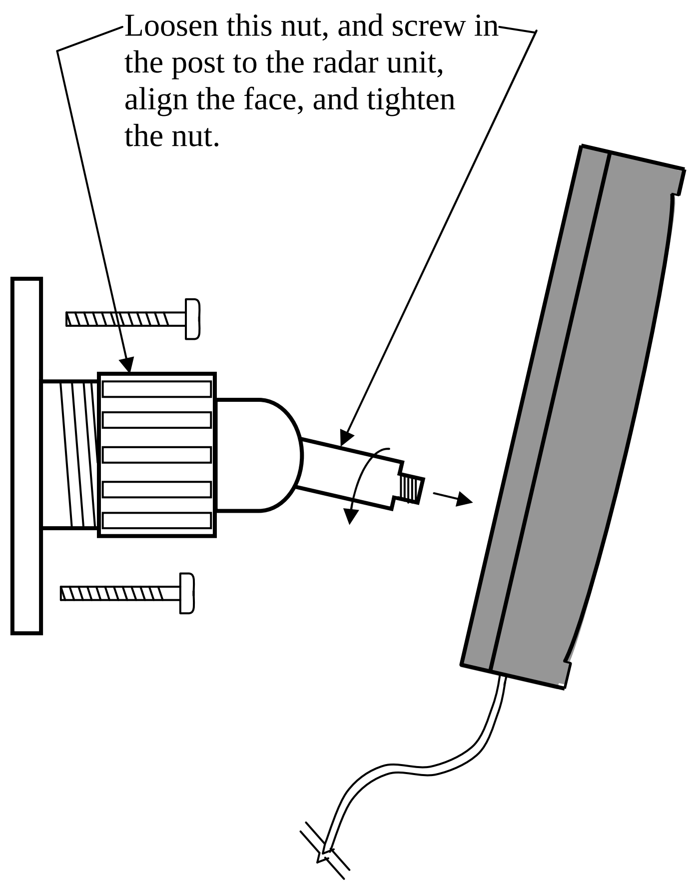
MOUNTING THE RADAR UNITS:

Reference Figure 4, Mount the bracket base at the desired locations(s) using the appropriate hardware:

a. For mounting to a wooden structure drill two 5/32 holes and secure bracket base with the screws provided.
b. For mounting to a masonry structure drill two 5/16 holes, and secure bracket base with the screws provided.
c. For mounting to a metal fence, post or bar, use the tie wraps provided. Secure 2 tie wraps per hole (4 per bracket base) and attach as required based on the installation.

Loosen the bracket nut, and attach the radar unit to the swivel bracket. Align the face of the radar unit approximately perpendicular to the line of the target travel, and tighten the bracket nut. It is not critical to get the face of the radar unit "perfectly perpendicular" to the line; this will not affect the accuracy of the readings. However alignment should be close enough so the ball travel is within the viewing field of the radar unit (reference Figure 1).

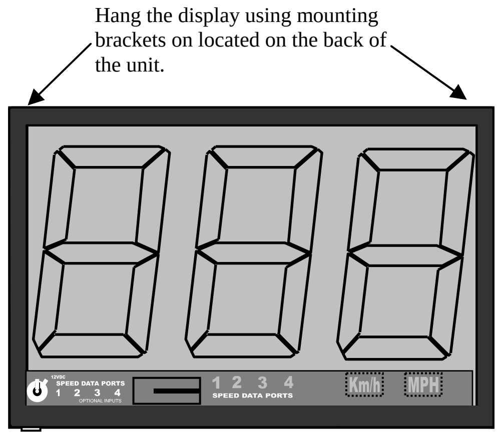
Figure 4, mounting the radar unit.



MOUNTING THE DISPLAY:

The display is mounted by the two brackets attached to the top of display. The multitude of variations at the specific installation prohibits a detailed description of each mounting method, however the following general guidelines are provided:

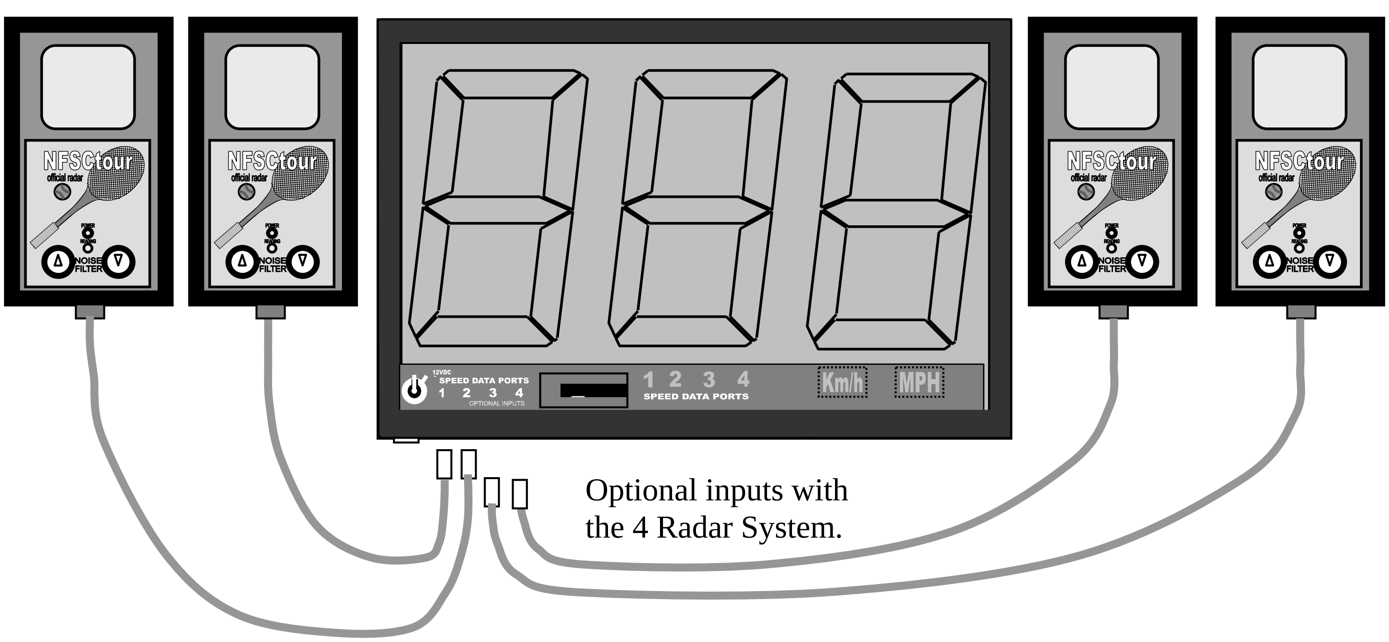
1. Must be located within 6 feet of an indoor AC power outlet.
2. Should be located for optimal visibility for fans and participants at the tennis court.
3. Securely affixed to a wall or other sturdy structure via the 2 mounting brackets.
4. Located as close as possible to all radar units. For a 4 unit installation, this would typically be center court, on either side. For a 2 unit installation this would be centered at the end of the court where the radar units are mounted.



ELECTRICAL CONNECTIONS

Power / Data cable for the radar unit.
The radar unit has a permanently attached Power / Data cable with an RJ45 plug. This is a dedicated plug, and should only be connected to equipment using the proper adapter. DO NOT CONNECT THIS TO A PC or other equipment or network connection, damage to the Radar unit and / or the connected equipment can occur. Figure 5 shows the connections between the radar units and the display. All cables should be routed and secured at each 5 foot length with the tie wraps. The multitude of variations at the specific installation prohibits a detailed description for each routed wire, however the following general guidelines are provided:

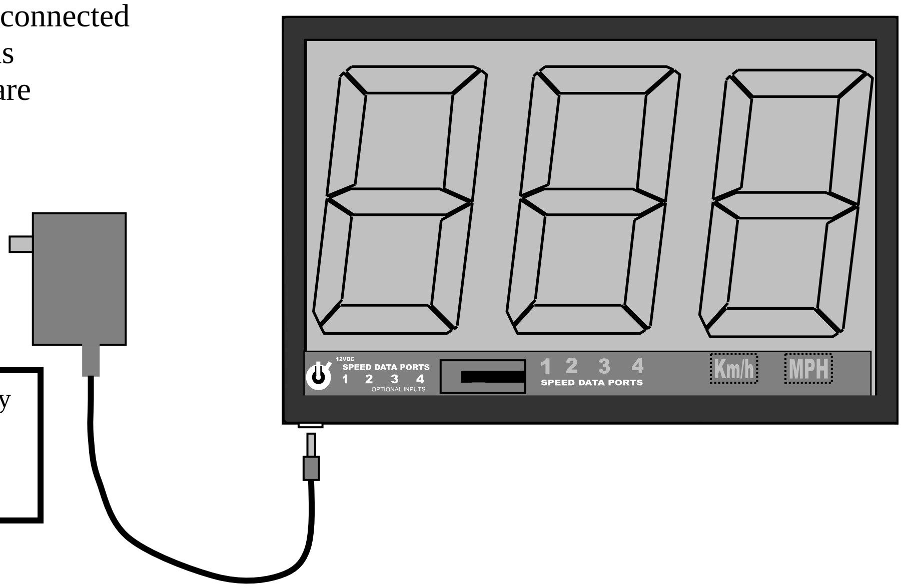
1. Must not be laid on the ground or floor.
2. Use only the supplied NFSC RJ45 to DB9 adapter for connecting to a PC, or only connect to a Sports Radar Ltd. display.
3. Should be secured at 5 foot intervals to a wall or fence to prevent tension at any point in the cables.
4. Should be routed in the shortest possible route.



POWER CONNECTION

Power for the NFSC speed measuring system is provided by a single 12 VDC, 1A power supply connected to the DC jack at the bottom left of the display. When the radar units are connected to the display, and the power supply is connected to the display, all devices are powered up.

Plug the power supply to an indoor standard N.A. 110V AC outlet.



CAUTION: do not connect the power supply to an outdoor outlet, avoid wet or damp areas; an electrical shock hazard can cause permanent physical damage or death.

Operating instructions

Once the installation is complete and the 12VDC power supply is connected to the display:

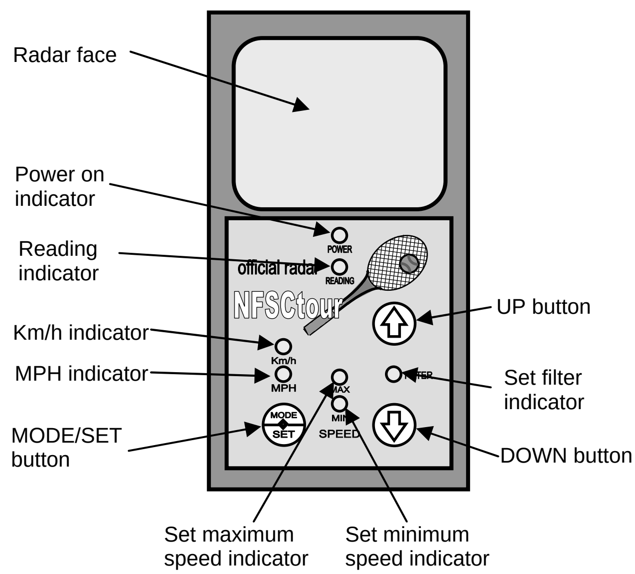
1. The display will count down from 999 to 000. Verify all digits are operating properly.
2. The POWER (Green) LED on each radar unit turns on, then after about 3 seconds all LED indicators blink on off and the READING (red) LED on each radar unit will turn on.

Strike the 65MPH tuning fork to make it “ring” and hold it in front of each radar unit, 1 at a time. The display should blank, then show “065 +/-2” for each radar unit.

On the front of the radar unit there are three buttons MODE/SET, UP arrow, and DOWN arrow.

MODE/SET Functions: *Must be connected to a display or PC to change these settings.*

1. Pressing the MODE/SET button changes the displayed units, either MPH or Km/h. The speed units are indicated by the indicator lights above the units.
2. Press and hold the MODE/SET button for about 3 seconds until the MIN (red light) turns on. Then the minimum speed limit can be adjusted up or down using the up and down buttons. When the desired minimum speed is set, press MODE/SET again, and the SET MAX (red light) turns on, and you can set the maximum speed using the up and down buttons. When the desired maximum speed limit is set, press MODE/SET and the radar is ready to read, and will only register speeds that are within the MIN and MAX speed limits set.



FILTER: *Must be connected to a display or PC to change these settings.*
The FILTER is a method to change the point at which the radar unit detects or registers a speed and is useful to reduce false readings from adjacent court play, or troublesome noise sources near the radar unit. Increasing the FILTER (the up button) filters out unwanted readings. Decreasing the FILTER (the down button) gives the radar unit more range, or the ability to register the speed of a target farther away, but also makes the radar unit more susceptible to undesired readings.

To increase or decrease the filter, press the UP or DOWN button (without first pressing the MODE/SET button), the red FILTER indicator light turns on, and the filter can be adjusted up or down as required. When the desired filter number is displayed, press the MODE/SET button.
The FILTER is factory set for typical installations; however, the specific installation may require some adjustments to the FILTER number:

1. If false readings are a problem, increasing the FILTER number can reduce or eliminate this. Filter numbers of 20 or 30 may reduce the range so the intended target may not register a speed. After the FILTER is adjusted, always test the radar unit to make sure it still has the range necessary to read the speed of the intended target. NOTE that if the false readings are not in the speed range that you intend to measure, setting the speed limits is the recommended method to exclude these readings.
2. If increased range is necessary at the installation, decreasing the FILTER number can provide additional range. NOTE that filter numbers of 5 or less are not recommended as this can degrade the accuracy of the unit and increase the susceptibility to noise and false readings.

Resetting to FACTORY settings:

The Radar unit can be reset to initial factory settings by holding the MODE/SET button down when power is applied.
The factory settings are:

Minimum speed = 25MPH (40Km/h)
Maximum speed = 175MPH (282Km/h)
Filter = 8
MPH on

TABLE 1:

Radar unit position factors for courts based on the base-line to back fence or wall distance:

Distance from base line to back wall	distance from centerline	mounting height
16 feet	4 feet	11 feet
18 feet	4-1/2 feet	11-1/2 feet
20 feet	5 feet	12 feet
22 feet	5 feet	12 feet
24 feet	5-1/2 feet	12-1/2 feet
26 feet	5-1/2 feet	13 feet
28 feet	6 feet	14-1/2 feet
30 feet	6-1/2 feet	14 feet

COSINE ERROR PROPERTIES

The COSINE error affects all Doppler radar speed measuring devices. When the COSINE of the angle is zero, the Doppler “sees” the target at 100% of it’s real speed. When the angle between two lines (defined below) is greater than zero, the Doppler radar device “sees” the speed LESS than the actual target speed. Two lines make up the COSINE angle (reference figure 3-1) and are defined as:

1. The line of the radar unit position and the point it where it registers a speed
2. The line of target travel

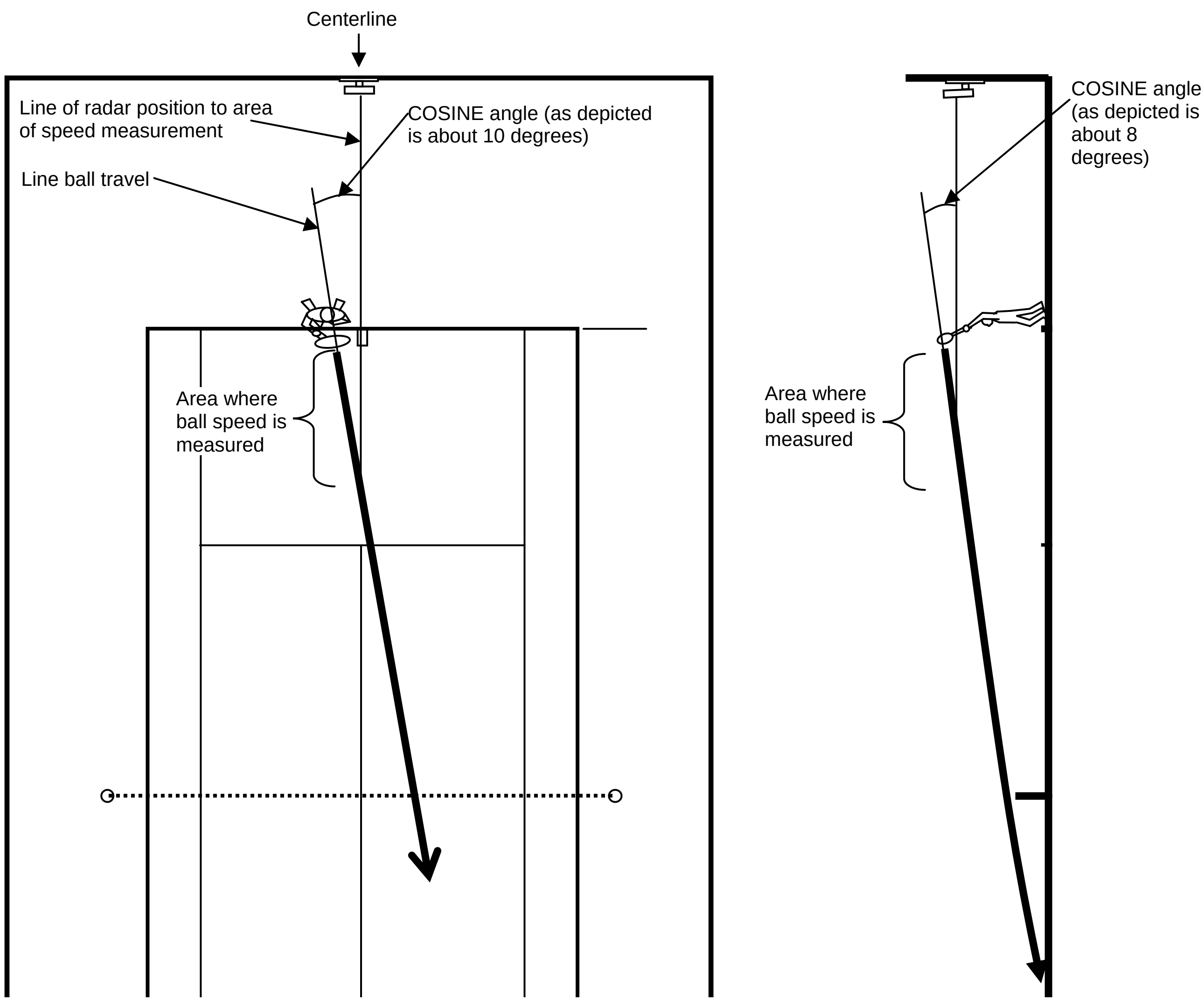
For purposes of the effect on Doppler radar units this is called the COSINE angle. The COSINE factor is a percentage of the actual target speed and is based on the COSINE angle. The COSINE angle and the COSINE factor are not linear, that is to say that if the angle changes by 10%, the factor will NOT change by 10%. Table 3-1 gives examples of COSINE angles and factors.
In real applications, such as measuring the speed of tennis serve, there are an infinite number of angles during the time the radar unit is measuring the speed (time taken when the racquet hits the ball and the speed is registered). This is inherent because the ball flight is never straight; it always has some “arc” to it. For practical purposes, this arc is minimal during the time the speed is being calculated, and is beyond the scope of discussion. Another, somewhat insignificant fact is that once the ball leaves the racquet it is decelerating due to the friction of air, which is also ignored for this discussion.
For optimum accuracy, if a line were drawn extending the line of flight of the target when the speed measurement is being estimated, the radar unit should be positioned on this line. In other words if the target were moving straight on this line in the direction of the radar unit, it would collide with the radar unit any position of the radar unit off this “collision course” makes a COSINE angle, and results in a registered speed that is less than the actual target speed. The actual reduction in calculated speed based on the COSINE angle is called the COSINE factor, examples of which are given in table 3-1.

TABLE 3-1, Cosine angles and factors

ANGLE	COSINE Factor		ANGLE	COSINE Factor
0 deg	1.000		8 deg	0.990
2 deg	0.999		10 deg	0.985
4 deg	0.997		12 deg	0.978
6 deg	0.994		14 deg	0.970

In order to achieve the desired radar unit location, it may be necessary to attach a brace or other construction to the fence (for outdoors courts) or back wall or ceiling structure (for indoor courts) if the specific court does not have a permanent structure at the desired back-wall location. NOTE: the location shown provides for optimum accuracy but is not a requirement of the installation for non NFSC tournament events, however the registered ball speed will be less than the actual ball speed by the cosine of the angle between actual ball travel and the optimal line at the point where the speed is registered. Figure 3-1 illustrates a cosine angle, and the reduction in registered speed for an installation where the optimal mounting height could not be achieved.

FIGURE 3-1



In this case, there are two COSINE error angles:

1. From the top view of the court, the angle is about 10 degrees based on a single radar installation.
2. From the side view the mounting location is lower than the optimal location, and results in about an 8 degree angle.

The resulting COSINE angle is greater than the largest angle, but less than the sum, or in this case about 12 degrees or a factor of about 0.98. The registered speed would be 0.98 x actual ball speed. So an actual ball speed of 100MPH would register at 98MPH.

TROUBLE SHOOTING:

1. Radar unit will not register a speed: First, reset the system by removing power from the display for 10 seconds, then re-applying power.
    a. Verify power is connected to the display (the radar units get power from the Power/Data cable from the display) If the display is active (counts down upon power up) then power is connected properly, at least to the display. On the radar unit, the POWER indicator (red LED) should be lit. If not, check the cable connections and the NFSC adapter is plugged securely in the display. Try plugging or swapping the power/data cable (and or the adapter) into a different port on the display. If this makes the unit POWER indicator turn on, either the cable, adapter or input port on the display is inoperable, or not making a good connection.
    b. Verify the READING (Green LED) is on. If not on, make sure the MIN, MAX and FILTER indicator LED's are off. If any of these are on, press the MODE/SET button, until all these indicators are off and the MPH and Km/H indicators toggle each time the MODE/SET is pressed. If the reading indicator does not turn on after a few seconds, the Radar unit is defective.
    c. Verify the MIN and MAX speed limits are set within the speed you are reading. To check this, press and hold the MODE/SET button until the MIN speed light comes on, the current minimum speed limit is shown in the display. Press the MODE/SET button again, and the MAX speed limit is displayed. Press the MODE/SET button again to exit the set speed limits mode.
    d. Verify the tuning fork registers 65MPH. If the POWER indicator, and the READING indicator are both on (MIN and MAX and FILTER indicators are off) strike the tuning fork to make it ring, and hold it about 1 foot in front of the unit. If the Reading indicator goes off, but the display still does not register the speed, this indicates the radar unit is operating properly, and the problem may be in the cable, or cable connection or adapter, or possibly in the display. If there are more than one radar units connected to the display, and any one of them makes the display show the speed, then it is most likely a connection problem in the data cable. You can "swap" inputs (and adapters) on the display, to see if the input port on the display (or the adapter) is the problem. Check the connection pins on the cables for corrosion, clean or replace as necessary. If no input configuration operates with multiple radar units, then the Display inputs may be defective, and will need factory service. If other radar units work, but one is not, then most likely the radar unit is defective.

2. Radar works with a tuning fork, but will not read a serve speed. If all items in 1 above are OK check the following with a display or PC connected:
    a. Verify the FILTER setting is not too high. With the POWER and READING indicators on (and MIN and MAX and FILTER indicators are off) Press the DOWN button, the FILTER indicator turns on, and the display shows the filter number. Adjust this to 5 using the UP and DOWN buttons, then press MODE/SET button. This low of a filter setting may give false readings, but it provides for maximum range. The maximum range of the radar unit is typically 25 feet, so make sure the distance from the radar unit to the serve line is less than 25 feet.
    b. If step (A) above allows the radar unit to read the ball speed, it is recommended that the filter number be increased to the point where it will not read the speed (MAX number, then adjusted back down, ½ way between 5 and the MAX number.
    c. If step (A) above makes the radar unit continuously false read, press the UP button, then the MODE/SET button, repeating this until the false readings stop. Verify the radar unit reads the intended target (serve a ball). If the speed can not be registered, then there is a noise source too close to the radar unit for the range to base line distance. The noise source must be shielded or eliminated, or the radar unit must be positioned CLOSER to the base line.

The NFSCtour Radar unit has features that can reduce or eliminate "false readings" due to various noise sources at the specific installation. It is important to understand why a Doppler radar unit may give a false reading, or register a speed, when in fact there was no intended target. The NFSC radar units detect motion, any motion. Undesired motion that the radar unit "sees" is called noise. Noise sources come in many forms, some you can see, some you can hear, and some that only the radar unit can detect. In the application, the radar units are always on, looking for a constant frequency, called the Doppler frequency over a specific time. The Doppler frequency, which is proportional to the ball speed, is what is used to estimate the actual ball speed. For instance, if the radar unit sees a fan, it will detect a constant frequency and may display a speed that is proportional to the speed that the fan blades are spinning, this is undesired noise. A large power transformer is another example of noise. You may have heard a power transformer "buzzing"; this buzzing is actually a vibration that the radar unit can detect as a false reading. Another, less apparent, is fluorescent lighting.
In general the NFSCtour radar units are factory set to be trouble free from noise sources. However, if the installation is experiencing false readings, adjustments to the radar unit's filter and min / max speed settings can be used to eliminate false readings in most installations.