Mils/MOA & The Range Estimation Equations

A Basic Study for Shooters

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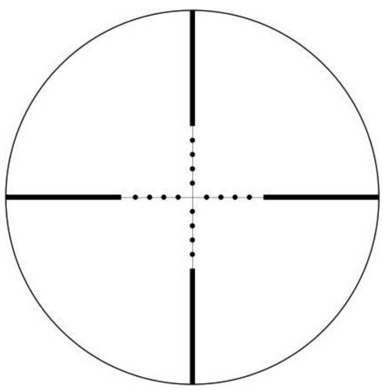
Overview

Many shooters use scopes that have reticles etched in mils or MOA to take measurements of targets. They then input those measurements into simple equations to estimate the distances to those targets. Based on those estimated distances, they then adjust their scopes' reticles using adjustment controls also calibrated in mils or MOA.

But what exactly is a mil or a MOA and how did they derive the range estimation equations? This paper will try to answer those questions, without getting to involved with the mathematics of the subject, so that shooters will have a better understanding of mils, MOA and the range estimation equations. Hopefully you will become a better-educated and knowledgeable shooter.

Note: This is an abbreviated version of my original paper titled **"Mils/Moa And the Range Estimation Equations, An In Depth Study For Shooters"** which is a little more math intensive.



Contents

1 Introduction

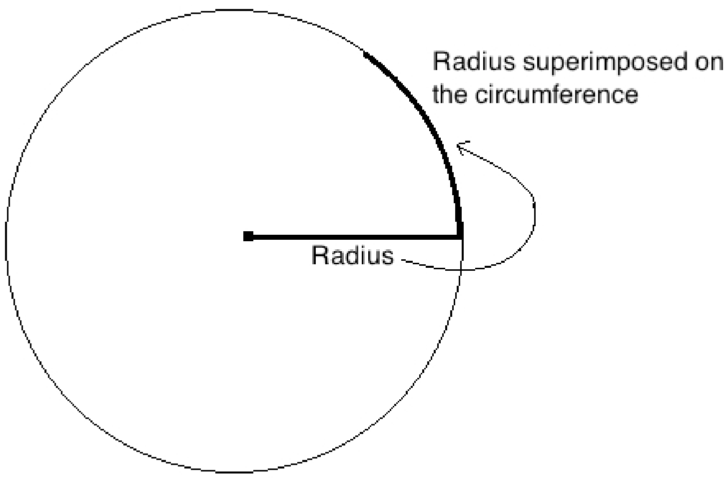
This paper is a shortened version of the paper I wrote titled, **"Mils/MOA and The Range Estimation Equations, An In-Depth Study for Shooters"**. This simplified version is for the shooter not really interested in the math behind range estimation yet still wants to understand the subject in a clear and easily understandable way. If you would like to see the more in-depth version, please see that original paper.

2 Mils

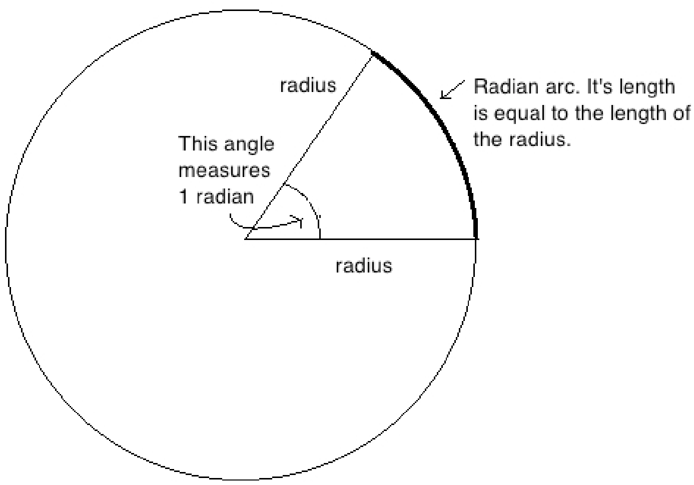
Mils have been used for many years as a mathematical tool to estimate the distances to targets. Used early on by artillery units, naval gunfire units, and most recently by snipers, mils are a valuable tool for accurate shot placement. But many people are unfamiliar with the term “mil”. So, what is a mil?

When shooters use the term “mil”, what they are really talking about is a shortened form of the word milliradian, which is a mathematical unit of angular measurement of a circle. The “Milli” part of the word “milliradian” is Latin and it means a thousandth (1/1,000th). For example, a millimeter is one one-thousandth (1/1000th) of a meter. In the same manner, a milliradian (usually shortened to just “mil”) is one thousandth (1/1000th) of a radian.

So what is a radian? A radian is an angle based on the properties of a circle. To use the natural physical properties of a circle to define what a radian is: (1) make a circle of any size, (2) superimpose the radius of the circle onto the circumference of the circle (below).



The portion of the circumference "covered" by the superimposed radius is called the "arc" or "radian arc". Remember, **the arc length is the exact same length as the radius**. Now connect the other side of the arc to the center with another radius, creating a pie shape. The central angle formed by this pie shape is called a "radian" (below).

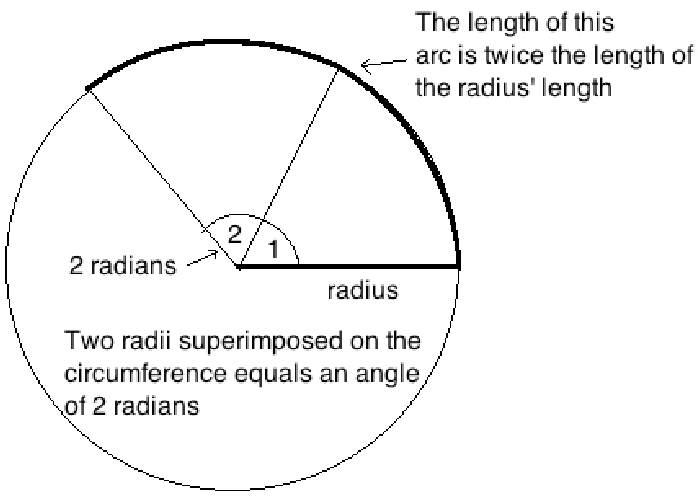


Radians are units of angles just like the more familiar degrees are; they're just an alternative way of measuring them. They use the actual radius of a circle to define the angle instead of some arbitrary man made number like 360°. Believe it or not, 360 degrees in a circle is an arbitrary man made number. Radians have advantages in math, science, and engineering that make them much more simple and advantageous to use (although those advantages are beyond the scope of this paper).

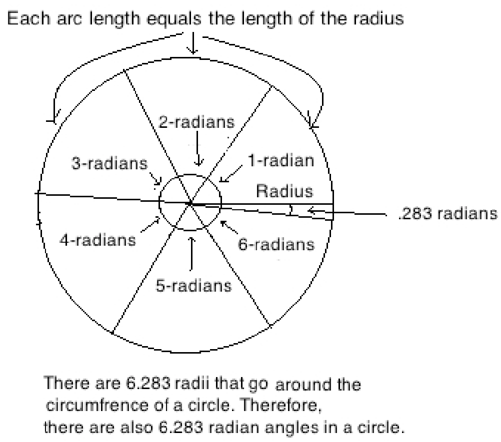
Note: A "radian" or "1 radian" means the same thing. It's just like saying "a degree" or "1 degree".

The example above showed what 1 radian is. **One-radian is based on the arc length being exactly the same length as the length of the radius.** But the arc length doesn't always have to be the same length as the radius' length; it can be longer or shorter. In those cases, we'll have radian angles that are also larger or smaller than a 1 radian angle. Let's look at some examples of what multiple radians, as well as fractions of radians, look like to show you what I mean.

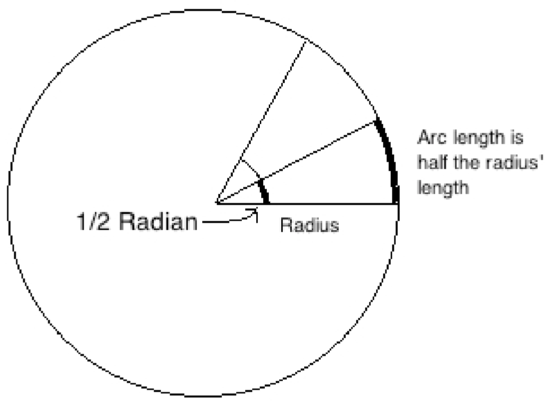
Two radians would be created by two radii (the plural of radius) superimposed on the circumference of a circle, creating an arc length twice the size of the radius's length, and would look like this:



If we continue adding radii to the circumference and go around the entire circle, it would take approximately 6.283 radius lengths to go around the full circumference of a circle. Therefore, there are 6.283 (approximately) radians in a full circle (below).

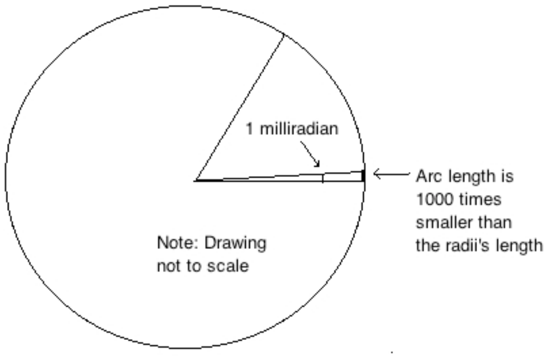


Going the other way, 1/2 radian means the arc length that is superimposed on the radius is only 1/2 the size of the radius's length, thus making the angle only 1/2 radian (below).



A fundamental point to emphasize, as you can see in the examples given so far, is that the angle is directly related to the arc length. That is, **the length of the arc directly dictates the size of the angle**. This fact is important to remember, especially when you look at the next example below.

If the arc length superimposed on the circumference is 1,000 times smaller than the radius' length, the angle created is 1,000 times smaller than a radian, which means the angle is $1/1000^{th}$ of a radian in measurement. As discussed on page 1, since it's 1,000 times smaller than a radian, it's called a milliradian, or a "mil".

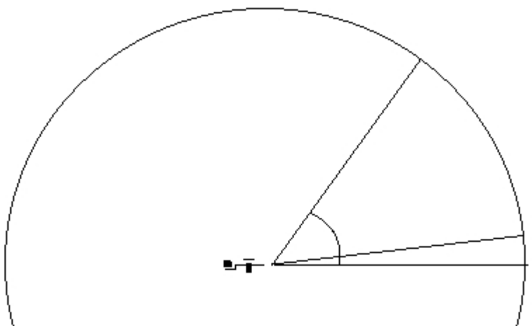


Note: We will now use the word "mil" or "mils" mostly from here on out.

So that is what a mil is; it's an angle 1,000 times smaller than 1 radian, where the arc length of that angle is 1,000 times shorter than the radius' length.

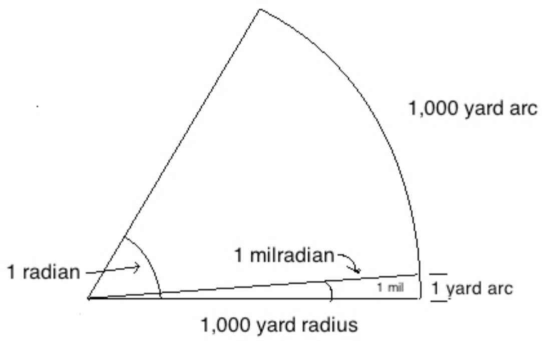
Note: Since there are 6.283 radians in a circle (previous page) and each one of those radians contains 1,000 miliradians (mils), then there are approximately 6,283 mils in a circle.

At this point in the discussion, I want you to now visualize that a shooter is at the center of a circle, because theoretically, that is really where a shooter is when using mils to measure angles (below).



Let's continue to look at some further examples of mils, this time with actual numbers in them, to get a better understanding of mils and how they can be used.

If the radius of a circle is 1,000 yards long, we know an angle of 1 radian has an associated arc length also 1,000 yards. It then follows that an angle of 1 mil, one thousand times smaller in angular measurement, must have has an associated arc length one thousand times smaller than 1,000 yards, which would be 1 yard (below).

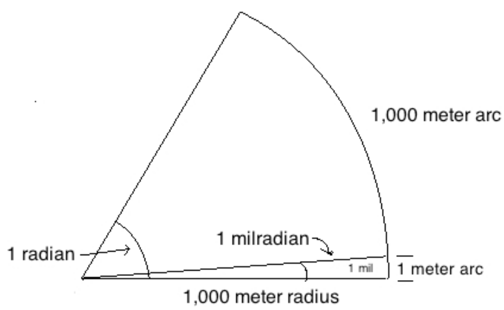


That is, at 1,000 yards, 1 mil has an arc length that is 1 yard in height. Or to put it another way:

"At 1,000 yards, 1 mil equals 1 yard".

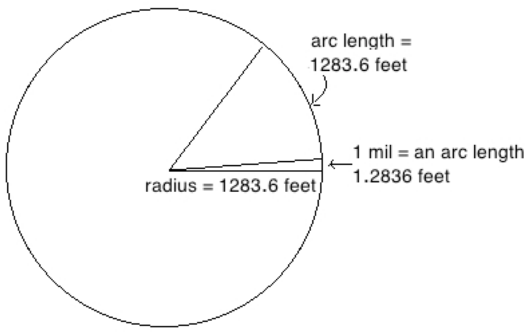
For many shooters, that is an expression that you might have heard before. Now you know where it comes from and why.

Using the same logic we can see that if the radius were 1,000 meters, a 1 mil angle would have an arc length that is 1 meter in height:



Therefore, "at 1000 meters, 1 mil equals 1 meter".

As you can see, it's very easy to visualize the relationship between the angle of 1 mil and the height of the associated arc when using easy numbers like 1,000. But it works for any number. For example, if the radius were 1283.6 feet in length, then a 1 mil angle would have an arc 1,000 times smaller, or 1.2836 feet in length:



The reason for this, as you can see in the three examples just given, is because a radian expresses a ratio of the length of the arc to the length of the radius and is **independent of the units** used.

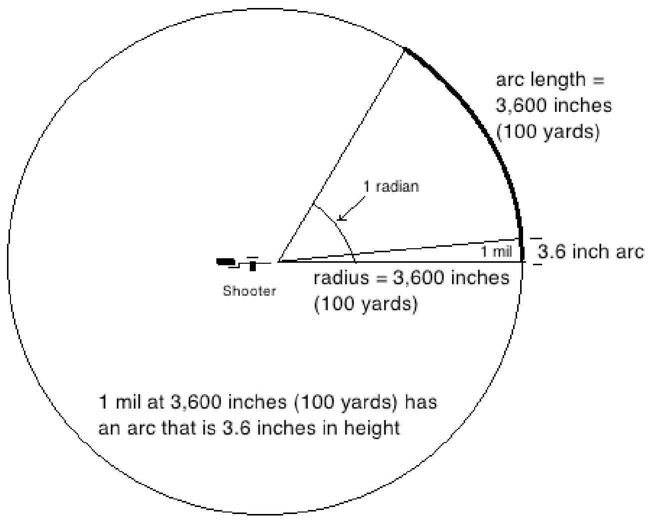
Let's look at two more common distances that shooters frequently use and are familiar with to not only solidify our understanding of mils, but also to show you where two more common shooting phrases come from.

American shooters are very familiar with the distance of 100 yards. But for this example of 100 yards, I want to first convert it to inches (you'll see why I did this shortly): A 100 yard shot converted to inches is:

$$36 \text{ inches per yard} \times 100 \text{ yards} = 3{,}600 \text{ inches.}$$

As you can see in the picture below, 1 radian at a radius of 3,600 inches has an associated arc length of 3,600 inches long. It then follows that 1 mil, 1,000 times smaller in angular measurement, has an associated arc length that is 1,000 times smaller than 3,600 inches, which would be 3.6 inches. Or put more simply:

"At 100 yards (3,600 inches), 1 mil equals 3.6 inches."

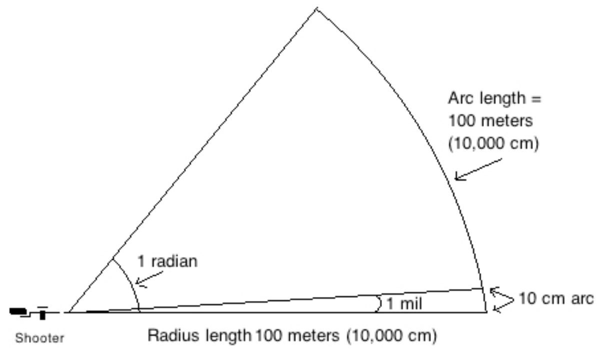


If we were talking about meters, with each meter having 100 centimeters (cm) in them, that means at 100 meters we have 10,000 cm (below):

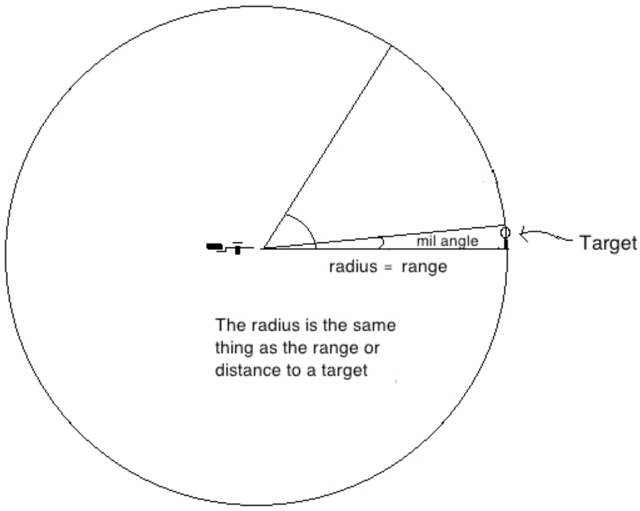
$$100\ \cancel{\text{meters}} \times \frac{100\ \text{cm}}{1\ \cancel{\text{meter}}} = 10,000\ \text{cm}.$$

Therefore, a mil would have an associated arc length 1,000 times smaller than 10,000 cm, which would be: 10,000 cm $\div$ 1,000 = **10 cm**. That is:

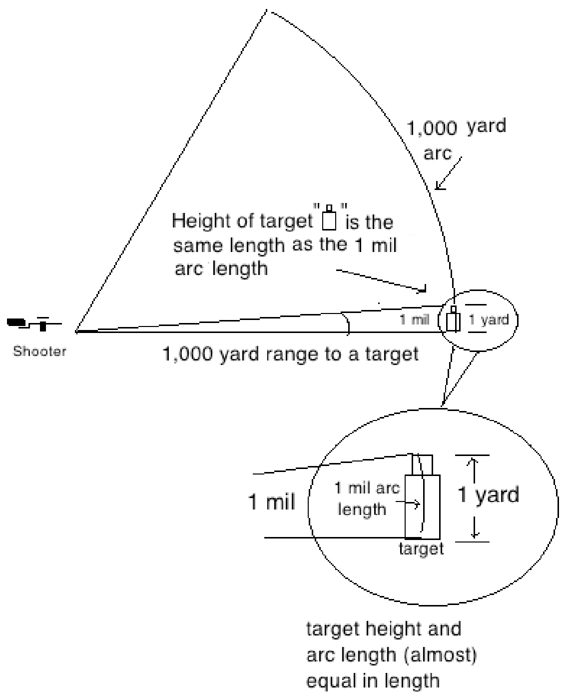
"At 100 meters, 1 mil equals 10 cm".



I'd like to point out two observations. As you can see in the previous pictures, from a shooter's perspective, the radius is the same thing as the range or distance to the target. Therefore, from here on out, I will mostly be using the terms "range" or "distance to the target" instead of the radius (below).



Also, as you can see in the picture above, the arc length can be thought of as the height of the target. For example, as discussed previously, 1 mil at 1,000 yards covers an arc that is 1 yard in height (see page 6 again). Now think of the arc height as the height of a target (below).

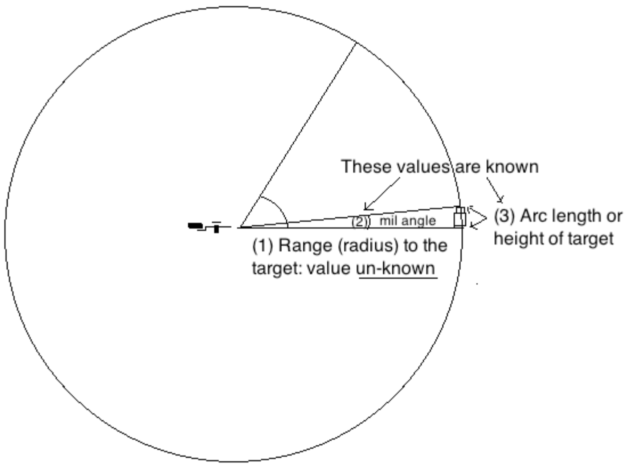


Note: Because targets are measured in straight lines from top to bottom, they are slightly shorter in length than the curved arc of a circle. At shooting distances and *at these small angles, for all practical purposes we can consider the difference in length to be negligible and its effects on the math are insignificant.*

3 The Mil Range Estimation Equation

With this knowledge of mils and how they relate to a circle, we can use the naturalness of mils and some simple math to come up with an equation to get the distance to a target.

For shooters, we must know the mil angle and the height of the target beforehand to figure out the range to the target (below).



Bypassing the math derivation for this paper, the basic equation to determine the range or distance (D) to a target in its simplest form is; the height (H) of a target multiplied by 1,000 divided by the number of mils (X) equals the range or distance to a target.

$$\frac{H \times 1,000}{X \text{ mils}} = D \text{ (distance)}.$$

Let's see how this equation works using some previous examples that we already know the answer to.

Say we are shooting at an object that is 1 yard in height and it covers 1 mil in our scope. How far away is it? Plug the numbers in the equation and solve:

$$\frac{1 \text{ yard} \times 1,000}{1 \text{ mil}} = 1,000 \text{ yards.}$$

The distance to the target is $1,000$ yards away, just as we knew it should be (see page 6 again).

Here's another example that we already know the answer to (see page 8):

You see an object that you know is 3.6 inches in height and you see it measures 1 mil in your scope. How far away is the object? Plug the numbers in the equation and you get:

$$\frac{3.6 \text{ inches} \times 1,000}{1 \text{ mil}} = 3,600 \text{ inches.}$$

The 3.6-inch object covering 1 mil is 3,600 inches (100 yards) away, the same answer we got using a different method on page 8.

A very important point to make at this time is that **the units of measurement you use for the height of an object are the same units you will get for the distance.** That is, if you measure the height of an object in inches, the distance you get will also be in inches. If you measure the height of an object in centimeters, the distance you get will also be in centimeters etc. For example, if you're using **meters** for the height that you measure an object in, then the equation will look like this and your distance result will be in **meters**:

$$\frac{H \text{ meters} \times 1,000}{X} = D \text{ meters.}$$

If you're using **yards** for the height of the object you're shooting at, the distance will be in **yards** and the equation looks like this:

$$\frac{H \text{ yards} \times 1,000}{X} = D \text{ yards.}$$

I will use the equation for yards (above) to show how we can manipulate it to make it a little more user-friendly. The equation for yards is simple but not always practical. Let me show you an example of what I mean. Say there is a target of known height, $1/3$ of a yard, and it covers 2.25 mils in a scope. How far away is it?

$$\frac{\frac{1}{3} \text{ yard} \times 1,000}{2.25 \text{ mils}} = 148 \text{ yards.}$$

It's 148 yards away. But how many people measure the height of small targets in fractions of a yard? It's much easier to use inches. Yet if you use inches in the equation for the height, then the distance you get to it will also be in inches, and that's not practical either. For example, if you used inches for the height of the target in the previous example above, then the distance you would have gotten would also have been in inches:

$$\frac{12 \text{ inches} \times 1,000}{2.25 \text{ mils}} = 5,333 \text{ inches.}$$

As shown above, inches are not a very practical way to measure long distances. Therefore, using a simple conversion in the equation allows us to measure the heights of targets in **inches** yet gives us the distances to them in **yards**:

$$\frac{H \text{ in inches}}{36} = H \text{ in yards.}$$

The conversion is, height measured in inches divided by 36 equals the height in yards. Here are two examples:

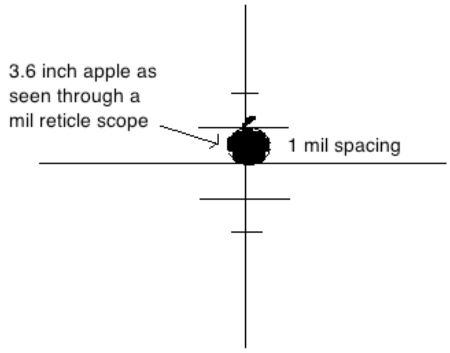
$$\frac{36 \text{ inches}}{36} = 1 \text{ yard,} \qquad \frac{12 \text{ inches}}{36} = 1/3 \text{ yard.}$$

This conversion substituted into the distance equation allows us to measure the heights of targets in inches but gives us the distances to them in yards (below).

$$\frac{H \text{ in inches} \times 27.8}{X \text{ mils}} = D \text{ yards.}$$

This new equation let's us use **inches** for measuring the height of an object yet at the same time, because of the conversion used, gives us the distance in **yards**. This is very advantageous, particularly to American shooters, who are used to these units of measurement for heights and distances.

Let's look at an example of how this new distance equation works. Say we're shooting at an apple that we know is 3.6 inches in height. Looking through our scope, we see that it fit's exactly between a 1-mil spacing in our reticle:



Plugging the numbers into our equation and then solving, we get:

$$\frac{H \text{ inches} \times 27.8}{X \text{ mils}} = D \text{ yards}$$
$$\frac{3.6 \times 27.8}{1 \text{ mil}} = D$$
$$D = 100 \text{ yards.}$$

Look familiar? Look at the picture on the top of page 8 again. One mil at 100 yards equals an object 3.6 inches in height. We got the same answer both times, just using different methods. One involved a conceptual picture (page 8) and the other used a simple equation (above). Also, unlike the example on the top of page 12 where we got the distance in inches, this time we got the distance in yards.

What if the apple measured only a $\frac{1}{2}$ mil (.5 mils) in the spacing on our scope's reticle; what would the distance to the apple be?

$$\frac{3.6 \times 27.8}{.5 \text{ mils}} = 200 \text{ yards.}$$

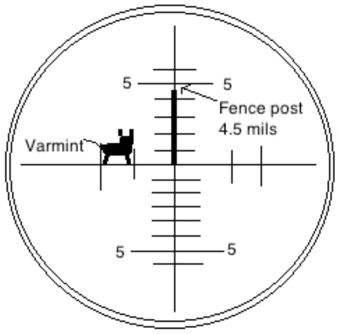
That makes sense, since the apple would appear to be smaller in our scope because it is farther away, thus covering only $\frac{1}{2}$ mil in our scope at 200 yards.

The beauty of the equation and the mil spacing on the scope is that estimating distances can be done quickly and easily with a simple calculation.

Let's look at one more example and show how a shooter really uses all the knowledge we've learned so far.

There is a varmint that has been eating some garden vegetables and we want to end that situation. We don't know the height of the varmint, but do see that he's near a fence post that we put up a few years ago and know is 48 inches in height above the ground. Looking through the scope, we see that the fence post covers 4.5 mils in the scope. How far away is that varmint?

(Scope etched in mils)



Plugging the known numbers into the distance equation:

$$\frac{H \text{ inches} \times 27.8}{X \text{ mils}} = D \text{ yards}$$
$$\frac{48 \text{ inches} \times 27.8}{4.5 \text{ mils}} = D \text{ yards}$$
$$D = 296 \text{ yards.}$$

Using the distance calculated by the range equation (roughly 300 yards) we can now adjust the scope for a 300 yard shot to the varmint.

Note: That was the last time that varmint ate the vegetables.

Many people around the world don't measure objects in inches or distances to targets in yards though. That's not a problem; the equation can be adjusted for any combination of units that you desire to use for measuring the heights of targets and the units you want for the distance to them, just like we did for the "inches to yards" example above. You can see page 25 at the end of this paper for the distance equations in mils using various units of measurements.

Summary of mils

Mils are not a familiar way of measuring angles for most people. As a matter of fact, most non-shooters or non-military people probably have never even heard of them before. But because of the "natural" way they are defined and the advantages that come with that, it is easy to come up with a simple equation for estimating distances to targets resulting in it being a valuable tool for shooters.

One last and important note on mils before we move onto the next unit of angular measurement is that the mils that we have talked about and studied so far are actually based on the real physical properties of a circle. They are a real trigonometric unit of angular measurement and are "true mils". That begs the question then, "what other kind of mils are there?"

Remember the note on page 5 when I said there were approximately 6,283 mils in an entire circle. The unevenness of this "true" number of mils in a circle provided problems for artillery units trying to do calculations quickly and could lead to mathematical errors with serious consequences. Therefore, they manipulated the angle slightly to make the number of mils in a circle more rounded and easier to use, accepting the slight error this caused in actual distance, which is not that big a deal for artillery. Therefore, some military units as well as other countries use a slightly different "artificial" number for the number of mils in a circle. For example, some artillery and naval gunfire units use 6,400 mils in a circle; the former Soviet Union uses 6,000 mils in a circle, Sweden used to use 6,300 mils etc. Therefore, their reticles and equations are slightly different based on the different mils used. Although rounding and the inherent slight errors caused by this was not a big deal for artillery, it is for rifles, therefore most, **but not all**, rifle scopes manufactured are calibrated in "true" mils. Therefore, you might need to do some research into the kind of mils your scope is calibrated in and the slightly different equations they would use if they are older or come from countries outside the U.S.

4 Minute of Angle (MOA)

In this section, we're going to talk about the other unit of angular measurement that shooters use, "minute of angle", abbreviated as MOA. MOA are based on degrees, which unlike mils, most people are familiar with. They are used quite often in shooting and have in fact been used by shooters for many more years than mils have.

Note: "Minute of angle", "MOA" or "Minute" all mean the same thing.

Early scopes mostly used just plain cross hairs in their reticles. Later on they were made so that the reticle could be adjusted for windage and elevation and the units they used were mostly in the units of MOA, usually in $\frac{1}{2}$ or $\frac{1}{4}$ MOA adjustment per click. We still see that today.

Starting in Vietnam and into the 1970's because of the military requirement for ranging for snipers, scopes started to come equipped with mil reticles. Unfortunately though, the scope manufactures and the military still kept their adjustments for windage and elevation in MOA, an entirely different unit of angular measurement than mils. (One can equate that to the speed limit on a highway being in miles per hour but the odometer in your car being in kilometers per hour. There is a conversion that you must do to equate the two). This mixing of systems was ill advised and complicated things for a long time. Only years later did scope manufacturers (by popular demand, I'm sure) finally start making scopes in the same units of angular measurement for both their reticles and adjustments; either with a mil reticle and mil adjustments, or a MOA reticle and MOA adjustments.

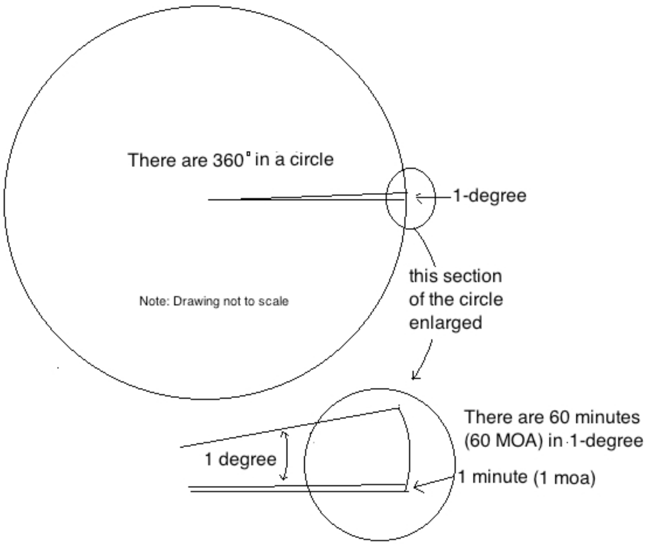
There is another slightly different version of MOA that shooters use and that some riflescopes are calibrated in. It's close in measurement to MOA (whom some call "true" MOA) in terms of measurement, but not exactly equal to it. It is referred to as **"inch per 100 yards"** (IPHY) or what some shooters call, **"shooter's MOA"** (abbreviated S-MOA). Similar to the discussion at the end of the mil section, this unit was made up so that measurements were more "rounded". Unlike riflescopes that mostly use "true" mils in their reticles, many scope manufactures do use S-MOA instead of "true" MOA in their reticles and/or adjustments. Therefore, we will discuss and analyze both types of MOA.

5 MOA Range Estimation Equation

There are 360 degrees (360°) in a circle.

Note: Why there are 360 of them is based on "man made" systems invented long ago by ancient mathematicians, but they are not based on the actual physical properties of a circle like radians are. Because degrees are man-made and don't have the "natural" properties that radians do, coming up with a distance equation mathematically for MOA (which we don't do in this shortened paper) is a little different than it was for mils.

Each degree contains 60 minutes or has 60 minutes of angle (MOA) in them. Another way of saying that is: 1/60th of a degree = 1 MOA.

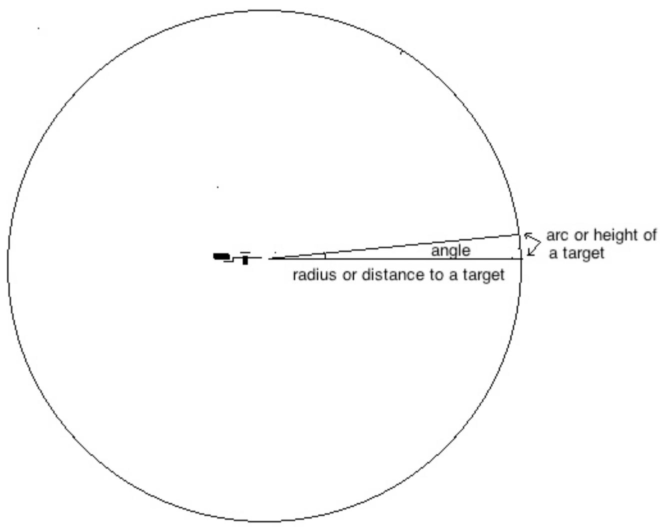


This means that there are a total of 21,600 minutes of angle in a circle:

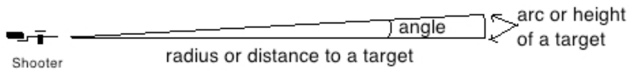
$$360^\circ \times \frac{60 \text{ minutes}}{1^\circ} = 360 \cancel{^\circ} \times \frac{60 \text{ minutes}}{1 \cancel{^\circ}} = 21,600 \text{ minutes}.$$

Since there are 21,600 MOA in a circle compared to 6,283 mils in a circle, MOA are a much finer unit of angular measurement than mils are.

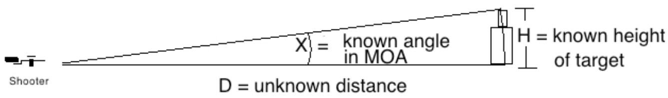
As previously with mils, picture a shooter at the center of a circle looking at a target (below):



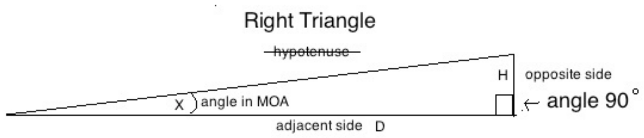
Let's disregard most of the circle so that we can concentrate on just the small pie shape again.



In our drawing of the geometry of a shot (above), notice we have what looks like a "right triangle" (below).



Recall, a right triangle has one angle of 90° (below):



The relationship of the sides and the angles of a right triangle are the basis of the subject of trigonometry.

Using trigonometry one can come up with the distance equation in its simplest form for scopes using MOA as the unit of angular measurement. If H is the height of a target and X is the angle in MOA, then:

$$\frac{H \times 3,437.75}{X} = D.$$

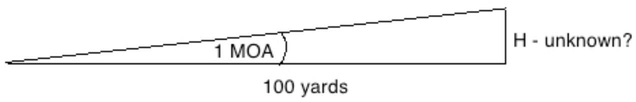
This basic equation (above) still looks cumbersome though and is not very user friendly. Therefore, just like we did with the mil equation, we can clean it up.

Recall from the section on mils that the distance equation gives you the distance to a target in the same units you used for measuring the height of a target (page 11). For American shooters, measuring the height of a target in inches and getting the distance to it in yards is advantageous. So let's make that substitution again here and simplify this equation.

Recall from page 12 that H/36 will convert inches to yards. Substituting that into the basic equation above, with H measured in inches and the output D in yards, the MOA distance equation now is:

$$\frac{H \text{ inches} \times 95.5}{X \text{ MOA}} = D \text{ yards.}$$

Now that we have this equation, let's use it to show you where a familiar shooting expression comes from. In this example, we want to know how much 1 MOA equals in height at 100 yards. That is, we know the distance and we know the angle, but we want to see how high a 1 MOA angle is at 100 yards.



To do this I'm going to adjust the equation to solve for the unknown value of H.

$$\frac{H \text{ inches} \times 95.5}{X \text{ MOA}} = D \text{ yards.}$$

Solve for H by cross-multiplying:

$$H \text{ inches} = \frac{D \text{ yards} \times X \text{ MOA}}{95.5}.$$

Plug in the known numbers, 100 yards and 1 MOA.

$$H \text{ inches} = \frac{100 \text{ yards} \times 1 \text{ MOA}}{95.5}$$

$$H = 1.047 \text{ inches.}$$

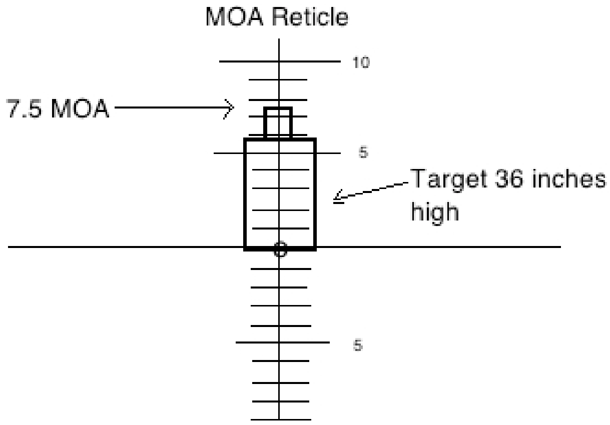
That is, at 100 yards, 1 MOA equals a height of 1.047 inches. Being so close to 1 inch, what many people commonly say though is:

"At 100 yards, 1 MOA equals 1 inch".

It must pointed out though, it's just a lucky coincidence that 1 MOA almost equals 1 inch at 100-yards, but it is very convenient.

Note: If you solve for the distance at where 1 MOA would give you exactly 1 inch, you would get 95.5 yards. That is, at 95.5 yards, 1 MOA equals 1-inch.

Here's an example of how a shooter would use the MOA distance equation: A shooter sees a target that he knows is 36 inches high and it covers 7.5 MOA on his scope. How far away is it?



Plugging the numbers in the equation and calculating:

$$\frac{H \text{ inches} \times 95.5}{X \text{ MOA}} = D \text{ yards}$$
$$\frac{36 \text{ inches} \times 95.5}{7.5 \text{ MOA}} = 458 \text{ yards.}$$

The target is 458 yards away.

The MOA equation with the “inches to yards” conversion of 95.5 is very simple to use, and being that 95.5 is so close to 100, if you have to calculate quickly, you can round up and do the math in your head fairly accurately. This leads us to our next discussion.

Note: See page 26 for other MOA equations using different units for heights and distances.

6 Shooter Minute of Angle (S-MOA)

Inch per 100 yards (IPHY) or Shooters-MOA (S-MOA)

With 1 MOA being so close to 1 inch at 100 yards (1.047 inches at 100-yards), shooters and manufactures of scopes decided to use a slightly smaller angle that will cover exactly one inch at 100 yards, or “inch-per-hundred-yards” (IPHY). Being so close to the MOA value of 1.047 inches, easier to say than “inch-per-hundred-yards” and likely invented by shooters, the angle became more popularly known as “shooters" MOA (S-MOA).

Note: Since "shooters MOA" is easier to say than "inch-per-hundred-yards", I will mostly use that term from here on out.

Many scopes do have their reticles calibrated in S-MOA and/or have their adjustments in S-MOA instead of "true" MOA. This has advantages in ease of use and the range equation (as you will see).

Because we wanted the S-MOA angle to be exactly 1 inch at 100 yards instead of 1.047 inches, it is a slightly smaller angle than 1 MOA, which recall is 1/60th of a degree (page 16). This new angle is actually 1/62.83 of a degree.

That also means that since there are 62.83 S-MOA per degree, and we have 360° in a circle, multiplying them we get 22,618.8 S-MOA in a circle.

Since there are 22,618.8 S-MOA in a circle compared to 21,600 MOA (page 17) in a circle, you can see that S-MOA is very close in size to MOA.

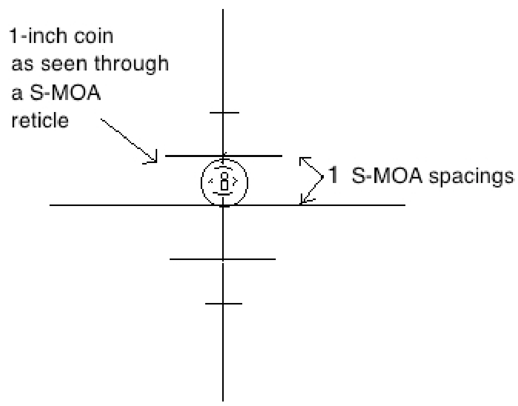
Using trigonometry again as was done for MOA, with *H* being the height of the target and *X* being the angle in S-MOA this time, we get the basic S-MOA equation of:

$$\frac{H \times 3,600}{X} = D.$$

The equation above says the height of an object in whatever units you use, multiplied by 3,600, then divided by the S-MOA angle, equals the distance to a target in the same units.

Originally we wanted an angle that would give us exactly 1 inch at 100 yards (which is the same as 1 inch at 3,600 inches) and here we have it. For example:

There is a target, a 1-inch diameter coin, and we see it fits exactly between 1 S-MOA on a scope. How far away is it?



$$\frac{1 \text{ inch} \times 3,600}{1 \text{ S-MOA}} = D$$
$$D = 3,600.$$

D = 3,600 inches, which as we know, is 100 yards. That is, a 1-inch object measuring 1 S-MOA on a scope is 100 yards away. Exactly what we originally wanted (page 20)

Let's now substitute the "inches to yards" conversion that we previously used (page 12), H/36, into the basic equation (above) to allow us to use inches for the height of an object yet get the distance to it in yards.

Now the equation for S-MOA with the height measured in inches and the distance given in yards is:

$$\frac{H \text{ inches} \cdot 100}{X \text{ S-MOA}} = D \text{ yards.}$$

If you plug in a height of 1 inch at an angle of 1 S-MOA, the distance equals 100 yards, meeting the original goal of 1 inch at 100 yards.

Here's another more realistic example. You see a vehicle that has wheels you know are 28 inches in height and it covers 4 S-MOA on your scope. How far away is the vehicle?

$$\frac{28 \text{ inches} \cdot 100}{4 \text{ S-MOA}} = 700 \text{ yards.}$$

It can quickly and easily be calculated that it is 700 yards away.

Note: See page 26 for other S-MOA equations using different units for heights and distances.

7 Conversion Between Units

Recall back on page 16, when I said some scopes use mils for their reticle but had their adjustments in MOA, two different units of angular measurement. In that case, when you wanted to make adjustments to your shots using your elevation and windage controls, you first needed to convert the observed amount your shot is off target in mils to an equivalent MOA value for your elevation and windage adjustments.

For example, if you look through your scope and you observe that you are shooting 2.5-mils low at 750 yards, how much MOA up do you need to adjust your elevation control to correct for that?

Let's review. From pages 5 and 17 we know that we have 6,283 mils and 21,600 minutes in a circle. If you take 21,600 minutes and divide that by 6,283.2 mils, you get:

$$\frac{21,600 \text{ MOA}}{6,283 \text{ mils}} = 3.438 \text{ minutes per mil.}$$

That is, there are 3.438 MOA per every mil. This is the conversion between these two units of angular measurement. Therefore, in the example above, if you were 2.5 mils low at 750-yards, you need to adjust your scope:

$$2.5 \text{ mils} \times 3.438 \text{ minutes per mil} = 8.6 \text{ minutes.}$$

You would need to adjust your scope 8.6 MOA up for the 2.5 mil low shot. If your scope had, as a lot do, 4 adjustment clicks per MOA in adjustment, then you would need to crank it up:

$$8.6 \text{ MOA} \times 4 \text{ clicks per MOA} = 34.4 \text{ clicks.}$$

Since you can't dial up .4 clicks, you could either dial it up 34 or 35 clicks to make the adjustment. **Note however that the distance (700 yards) plays no part in the conversion between the units, and never does.**

Therefore, to make a correction from your mil reticle to your MOA adjustments, all you need to do is the following:

(Correction in mils) $\times$ **3.438 = (Correction in MOA)**.

If you had a mil reticle and S-MOA adjustments, then the conversion is:

Recalling from page 21 that there are 22,618.8 S-MOA in a circle and 6,283 mils in a circle (page 5):

$$\frac{22,618.8 \text{ S-MOA}}{6,283 \text{ mils}} = 3.6 \text{ S-MOA per mil.}$$

That is, there are 3.6 S-MOA per every mil.

Note: That makes sense since we know that at 100 yards, (3600 inches), 1 mil equals 3.6 inches (page 8). Since we wanted our S-MOA angle to be exactly 1-inch at 3,600 inches, then there should be 3.6 of them per mil at 100-yards.

Therefore, using the same method as above for MOA, the conversion between mils and S-MOA is:

(Correction in mils) x 3.6 = (Correction in S-MOA).

It is very important to know what type of reticle you have and what your adjustments are calibrated in. Many scopes have mil reticles and MOA adjustments, but they could also have:

-Mil reticle and S-MOA adjustments
-Mil reticle and Mil adjustments
-MOA reticle and MOA adjustments
-S-MOA reticle and S-MOA adjustments

A major advantage of having your adjustments in the same units as your scope's reticle is that making adjustments to your shots is simple since there is no conversion required. All you have to do is measure how many mils, MOA or S-MOA (depending on whatever reticle you're using) your shot is off and adjust your elevation and windage controls the same number of units in the opposite direction, no matter the distance, with no conversion required. For instance, if you had a mil reticle and mil adjustment controls, then in the example on page 22 where your shot was 2.5 mils low, all you would need to do is adjust up 2.5 mils on your elevation control with no conversion required. Simple! Why it took so long to get reticles and their adjustment controls in the same units of measurement for riflescopes is beyond me.

Conclusion

I hope I achieved my goal of explaining the various units of angular measurment that shooters use in simple language. I also hope this knowledge makes you a better-educated and well-rounded marksman. Good shooting. Thank you.

Sincerely,

Robert J. Simeone

8 Distance Equations

Below are the distance equations for various combinations of reticles, units of height and distance. I derived them the same way I did on starting on page 12. Just put a conversion between units into the basic range equation and solve. Pick the equation that meets your needs in terms of your reticle and the units of measurement you prefer to use.

Mils

$$\frac{\text{Height of target (yards)} \times 1,000}{\text{mils}} = \text{Distance to target (yards).}$$

$$\frac{\text{Height of target (inches)} \times 27.78}{\text{mils}} = \text{Distance to target (yards).}$$

$$\frac{\text{Height of target (yards)} \times 25.4}{\text{mils}} = \text{Distance to target (meters).}$$

$$\frac{\text{Height of target (meters)} \times 1,000}{\text{mils}} = \text{Distance to target (meters).}$$

$$\frac{\text{Height of target (cm)} \times 10}{\text{mils}} = \text{Distance to target (meters).}$$

MOA

$$\frac{\text{Height of target (inches)} \times 95.5}{\text{MOA}} = \text{Distance to target (yards).}$$

$$\frac{\text{Height of target (inches)} \times 87.32}{\text{MOA}} = \text{Distance to target (meters).}$$

$$\frac{\text{Height of target (meters)} \times 3,437.75}{\text{MOA}} = \text{Distance to target (meters).}$$

$$\frac{\text{Height of target (cm)} \times 34.37}{\text{MOA}} = \text{Distance to target (meters).}$$

S-MOA

$$\frac{\text{Height of target (inches)} \times 100}{\text{S-MOA}} = \text{Distance to target (yards).}$$

$$\frac{\text{Height of target (inches)} \times 91.44}{\text{S-MOA}} = \text{Distance to target (meters).}$$

$$\frac{\text{Height of target (meters)} \times 3,600}{\text{S-MOA}} = \text{Distance to target (meters).}$$

$$\frac{\text{Height of target (cm)} \times 36}{\text{S-MOA}} = \text{Distance to target (meters).}$$

9 Quick Reference Guide

- At, 1,000 yards, 1 mil equals 1 yard: page 6.
- At 1,000 meters, 1 mil equals 1 meter: page 6.
- At 100 yards, 1 mil equals 3.6 inches: pages 7 and 8.
- At 100 meters, 1 mil equals 10 cm: pages 8.
- Basic Distance equation for mils: page 10

$$\frac{H \times 1,000}{X \text{ mils}} = D.$$

- Common mil distance equation for American shooters: page 12.

$$\frac{H \text{ inches} \times 27.8}{X \text{ mils}} = D \text{ yards}.$$

- Basic MOA equation: page 18.

$$\frac{H \times 3,437.75}{X \text{ MOA}} = D.$$

- Common MOA distance equation for American shooters: page 19.

$$\frac{H \text{ inches} \times 95.5}{X \text{ MOA}} = D \text{ yards}.$$

- 1.047 inches per "true" MOA at 100 yards: page 19.
- Basic Shooters MOA (S-MOA) distance equation: page 21.

$$\frac{H \times 3,600}{X \text{ S-MOA}} = D.$$

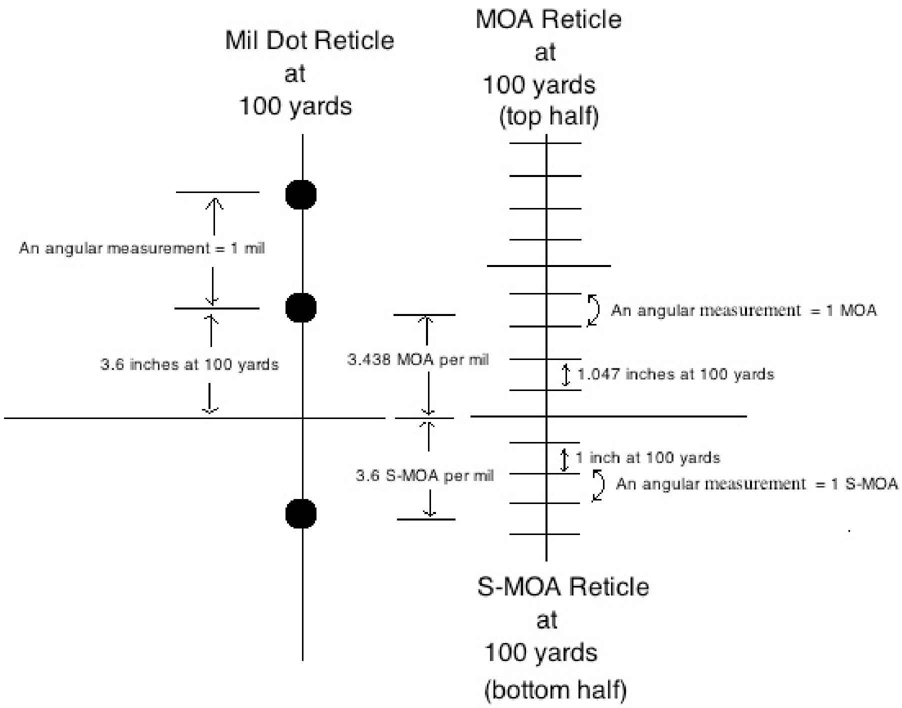
- 1 inch per "shooters" MOA (S-MOA) at 100 yards: page 22.
- Common MOA distance equation for American shooters: page 22.

$$\frac{H \text{ inches} \cdot 100}{X \text{ S-MOA}} = D \text{ yards}.$$

- 1 mil = 3.438 minutes (MOA): page 23.
- (Correction in mils) $\times$ 3.438 = (Correction in MOA): page 23.
- 1 mil = 3.6 S-MOA: page 23.
- (Correction in mils) $\times$ 3.6 = (Correction in S-MOA): page 23.

10 Comparison of Angles

This is a comparison of the three angular measurements (mils, MOA and S-MOA) at 100 yards. Don't confuse the angular measurement with what they cover in height. For example, at 100-yards, 1 mil covers 3.6 inches in height but is equal to the "angular measurement" of 3.438 MOA.

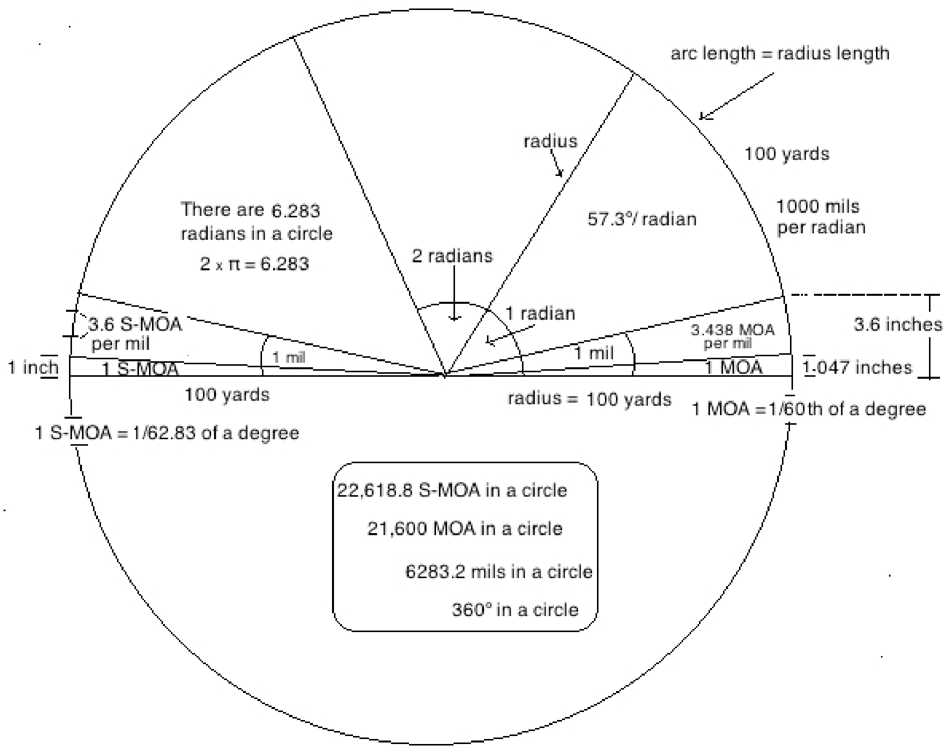


Note: Drawing not to scale.

11 The Big Picture

The Big Picture at 100 yards

(Note: The figure below is not to scale).



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