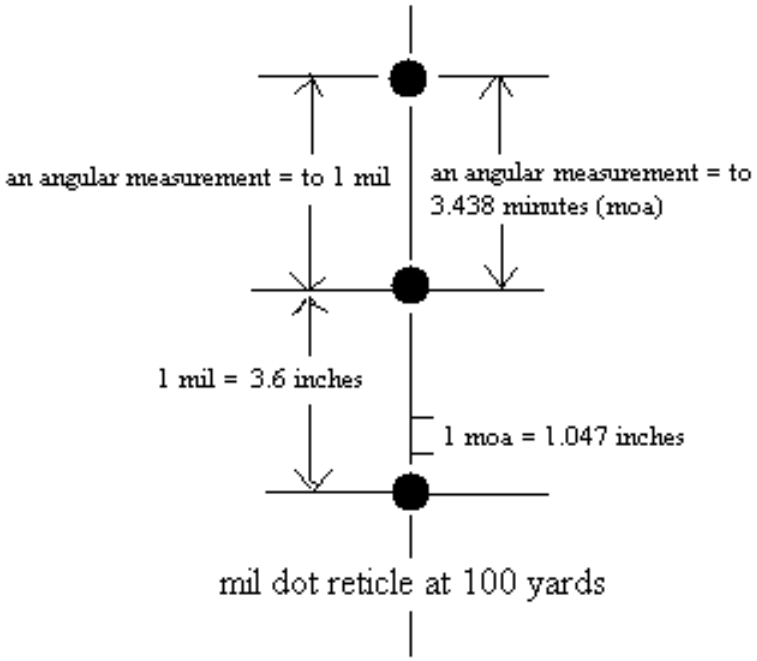
MILS and MOA

A Guide to understanding what they are and
How to derive the Range Estimation Equations

By Robert J. Simeone



$$\frac{\text{Height of Target (yards)}}{\text{mils}} \times 1000 = \text{Distance to Target (yards)}$$

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

$$\frac{\text{Height of Target (inches)}}{\text{moa}} \times 100 = \text{Distance to Target (yards)}$$

The equations for determining the range to a target using **mils**, and with some new scopes, **moa,** are:

$$\frac{\text{Height of Target (yards)}}{\text{mils}} \times 1000 = \text{Distance to Target (yards)}$$

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

$$\frac{\text{Height of Target (inches)}}{\text{moa}} \times 100 = \text{Distance to Target (yards)}$$

Has anyone ever wondered how they came up with these? Well I've wondered. I've read numerous accounts on the internet on "mils", but none of them explained how to actually derive these equations. They just seem to pull them out of the air at some point in their explanation of "mils" without actually showing us how or where they came from. I searched the internet far and wide, but to no avail. I was starting to wonder if they were derived so long ago that nobody knew how to do it anymore. So I decided to derive them on my own.

The reason I wanted to do that is because I feel that if you know how or why something works, or where it came from, you get a better understanding and appreciation of it, as well as its uses and limitations.

In this paper I will attempt to explain, in simple English and math, how they came up with these equations. I will try to keep it, to the best of my ability, simple, methodical (painfully in some cases), slow and easy to understand. So here it is.

First, a brief history of mils: A "mil" is a unit of angular measurement. The military's use of mils, which was used to help direct artillery fire, goes back as far as the late 1800's. Its modern form of use by the military for directing fire was developed in the 1950's. The modern "mil" is short for **milliradian, a trigonometric unit of angular measurement**. It is finer in measurement than degrees, thus more precise. In shooting, we can use mils to find the distance to a target, which we need to know, to adjust our shot. It is also used to adjust shots for winds and the movement of a target. (The actual techniques of how to use mils for shot adjustments are beyond the scope of this paper since this paper only deals with the math behind the equations). That's the short….very short….history of why we have and use mils.

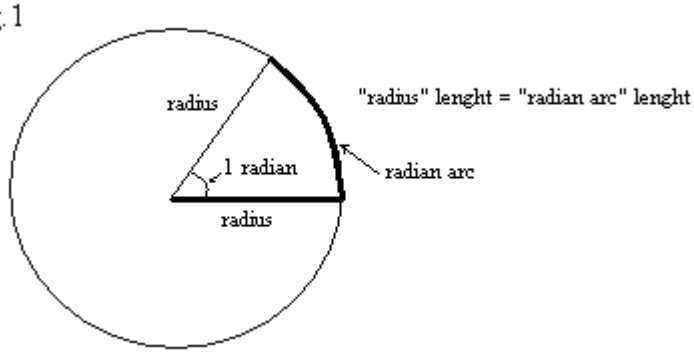
We are also going to talk about and define another term; **minute of angle,** or **moa**. It is another unit of angular measurement and used quite a bit in shooting. It is even smaller than a "mil". Usually, we range our targets in mils and adjust our scopes in "minutes of angle", or we talk about our "groupings" in moa. For instance, "my rifle shoots 1 moa all the time" or something like that. Also, some new scopes, like mine, now have reticles etched in minutes of angle (moa) rather than in mils. Therefore we will also derive the **moa distance equation**.

Before we can derive the equations, we need to define a few things and establish a few relations. So just follow along, hang in there, and you will see why we will need these later.

Radians

What is a radian? (Warning: you might have to read this paragraph a few times). A radian is a unit of angular measurement. Officially, one radian subtends an arc equal in length to the radius of the circle, "r". (Yeah that helps). How about this. What a radian is it associates an arc length, called a radian arc, which is equal in length to the radius of the circle, with an angle at the center of the circle. The angle the arc created is called a radian. Or, another way, it's the angle created at the center of a circle by an arc on the circumference of the circle, and that arc length is equal in length to the radius of the circle. Think of it as a piece of apple pie, where the two sides of the pie (the radii) are each equal in length to the curvature part of the pie (the arc). The angle created by the three sides at the center of the circle equals 1 radian (Fig.1).

Fig. 1



To find out how many "radians" (and /or radian arc's) are in a circle, we use the circumference formula of a circle, which is $C = 2\pi r$, where "r" is the radius. Take $2\pi r$ and divide by r. (Note: $\pi = 3.14159$)

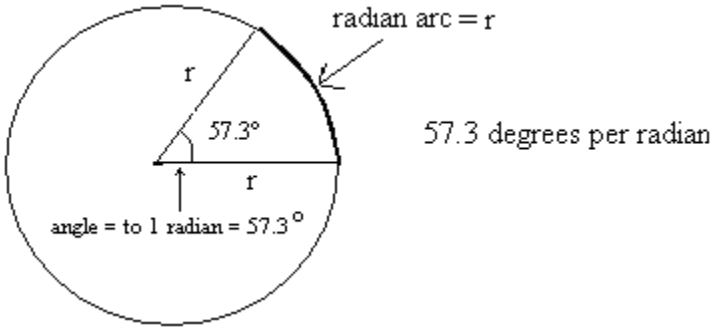
$\frac{2\pi r}{r} = \frac{2\pi \cancel{r}}{\cancel{r}} = 2\pi = 2 \times 3.14159 = 6.2832.$

Therefore, there are 6.2832 radians in a circle (or, 6.2832 radian arc's that go around the circumference of a circle).

No matter how long the radius "r" is, there will always be 6.2832 radians in a circle (because the "r" 's always get cancelled out in the arithmetic and all you're left with is 2π).

How many degrees are in a radian (or how big is the angle created by the radian arc)? Since there are 360 degrees in a circle and there are 6.2832 radians in a circle, then there are: 360/6.2832= **57.3 degrees per radian** in all circles no matter how long "r"is. (Fig. 2 below). Since there are 57.3°in each radian, and there are 6.2832 radians in a circle, then 6.2832 x 57.3° = 360° in a circle. Make sense?

Fig. 2



(A) Minutes in a Circle

There are 360 degrees in a circle, and each degree is composed of 60 minutes (60'). Therefore, there are 360 (degrees) x 60 (minutes) = **21,600 minutes in a circle** (21,600').

(B) Milliradians (mils)

What is a milliradian? A "mil" is defined as "one thousandth", or 1/1000. Therefore, a **millradian is 1/1000 of a radian**. Take each of the radians that go around a circle and chop it up into a thousand pieces. Since there are 6.2832 radians in a circle, and each radian is chopped up into a thousand pieces, then there are 6.2832 x 1000 = **6,283.2 milliradians in a circle**. (Milliradians is usually just shortened to **"mils"**)

(C) Degrees in a Milliradian (or degrees per mil)

I need to find out how many degrees are in each milliradian. A circle has 360 degrees, and/or 6,283.2 milliradians that go around it (**B** above). Therefore:

$$\frac{\text{360 degrees in a circle}}{\text{6,283.2 mils in a circle}} = .0573 \text{ degrees/mil.}$$

There are .0573 degrees per mil (degrees/mil)

(D) Minutes in a Milliradian (or minutes per mil)

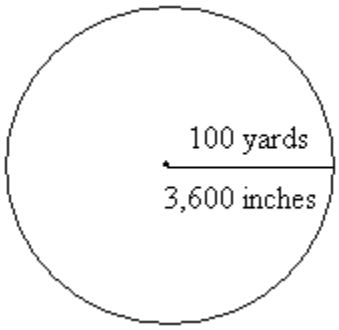
I also need to find out how many minutes (referred to as minutes of angle, or moa) there are in each mil. Let's review. We have 21,600 minutes in a circle (**A** above). And we have 6,283.2 mils in a circle (**B** above). Take 21,600 minutes and divide that by 6,283.2 mils and you will get 3.4377 minutes/mil. Let's shorten that to just **3.438 minutes/mil**.

Hang in there with me, just a few more things to figure out.

(E) Inches per Mil at 100 yards.

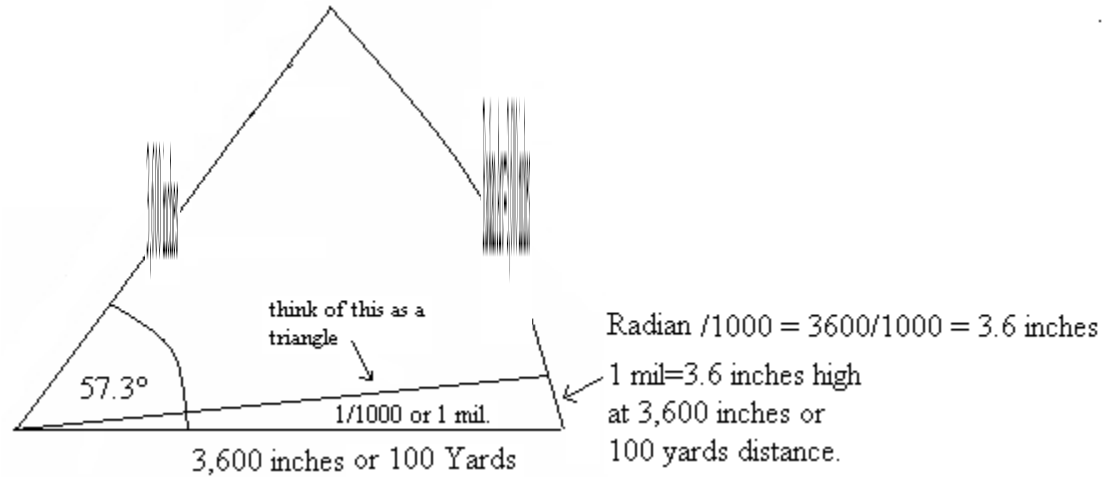
Look at the circle in Fig. 3 below. Make the radius 100 yards, or 3,600 inches long. (1 yard = 36 inches. 100 yards x 36 inches = 3,600 inches in 100 yards).

Fig. 3



Remember earlier from Fig.1 (page 3) that all the sides of the piece of pie are equal. Therefore, if one side is 3,600 inches, then all sides of the pie are also 3,600 inches (see Fig. 4 below). So what is 1/1000 of any of those sides, which would also be 1/1000 of the radian arc? Essentially, what is 1 mil equal to (remember, 1 mil is defined as 1/1000 of a radian)? 3,600 inches/1000 = 3.6 inches. (The drawing is not to scale, but you get the hint). **Therefore, at 100 yards, 1 mil = 3.6 inches.**

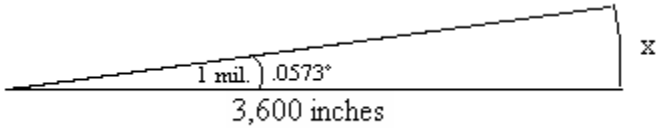
Fig. 4



For you math majors out there, another way to find the answer is to look at the bottom of Fig. 4 as a triangle (enlarged in Fig. 5 below). We want to find the value of "x" in Fig. 5. The way to do this is to use the **tangent** function of trigonometry.

We know the length of one side of the triangle, and the angle. But to use the tangent function, we need to convert the angle that is expressed in "mils" into an angle that is expressed in "degrees". Remember from **(C)** on page 4, **1 mil = .0573 degrees**. Now we can solve for "x".

Fig. 5



1) Tan θ = opposite / adjacent **2)** Tan .0573° = x / 3,600 in. **3)** 3,600 (Tan .0573) = x

(NOTE: using your calculator, the tangent of .0573 is .001)

4) 3,600 (.001) = x **5)** x = 3.6 inches

So 1 mil at 100 yards equals 3.6 inches.

Note: Even though the opposite side of the triangle "x" in Fig. 5 above is really not a straight line but a curve because it is actually a part of a circle, it is a very small curve. At this distance and at this small of an angle, for all practicable purposes we can consider it a straight line and its effects on the math are negligible.

(F) Inches per moa

This next part could be confusing, so follow the units here. Remember from **(D)** on page 4, there are 3.438 minutes per mil at 100 yards. Also, from **(E)** on page 5, there are 3.6 inches per mil at 100 yards. The question here is how many "inches per minute" are there at 100 yards? (Remember that 'minute' is an angular measurement like mils).

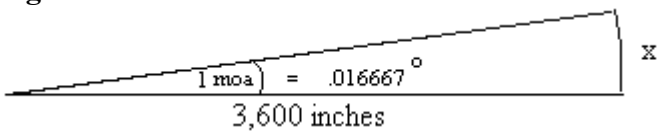
1) 3.6 inches per mil. / 3.438 minutes per mil. **2)** 3.6 inches ~~per mil.~~ / 3.438 minutes ~~per mil.~~

3) 3.6 inches / 3.438 minutes = 1.047 inches/minute

There are 1.047 inches per minute of angle at 100 yards (1.047 inches/minute).

Or another way to figure this out: (Reference Fig.6 below)

Fig. 6



1 minute (or 1 moa) equals 1/60 of a degree, which equals 1 divided by 60 = .016667 degrees. Just like the example above:

1) Tan θ = opposite / adjacent **2)** Tan .01667° = x / 3,600 in. **3)** 3,600 (Tan .016667) = x

(Note: the tangent of .016667 is .00029089)

4) 3,600 (.00029089) = x **5)** x = 1.047 inches

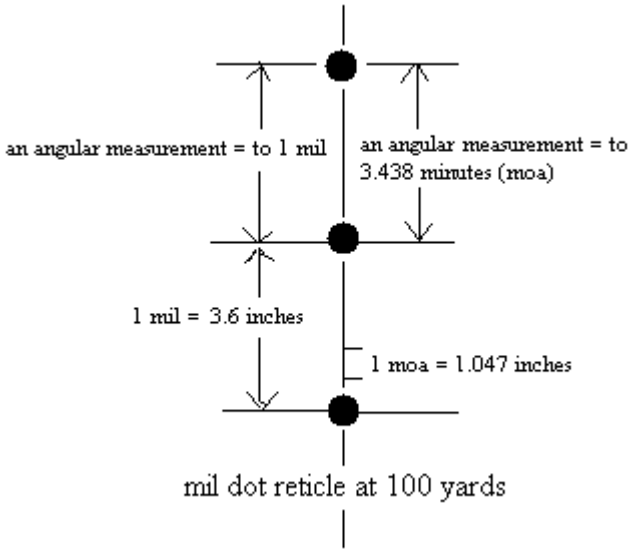
Or, one other way to figure this out (I promise, this will be the last way):

There are 3,600 inches in the radius of this circle. Therefore, the circumference of this circle would be 2π 3,600 = 22,619.467 inches.
Remember from **(A)** on page 4, there are 21,600 minutes in a circle.
Therefore, 22,619.467 inches/21,600 minutes = 1.047 inches per minute at 100 yards.

Talk about beating a dead horse!

So let's review. This is what we have while looking through a mil dot rifle scope at 100 yards. Each dot is separated by 1 mil.

Fig. 7



Let's do a little review here. Keep in mind that when we talk about "**mils**", we are talking about the angular measurement of a circle in "**milliradians**". And when we talk "**moa**", we are talking about the angular measurement of a circle in "**minutes",** which are a subset of **degrees**. They are two different angular measurements, but measuring the same thing, which in our case are small sections of a circle that look like triangles (see Figures 4, 5 and 6 above).

Remember, at 100 yards, each **1 mil angle** = **3.438 minutes of angle (moa)**, and each **1 minute of angle** has a length of **1.047 inches** (see Fig.7, page 7). Multiply those two numbers together:

$$\frac{3.438 \text{ ~~minutes~~}}{1} \times \frac{1.047 \text{ inches}}{1 \text{ ~~minute~~}} = \textbf{3.6 inches = 1 mil at 100 yards}$$

I hope you're starting to see the relationship between **mils** and **moa.**

Now, in the past when I've read about mils, somewhere around here is where they usually say:

"...and here is the equation that you use to find the distance to the target using mils."

(G)

$$\frac{\text{Height of Target (yards)}}{\text{mils}} \times 1000 = \text{Distance to target (yards)}$$

Well, where did they come up with this equation? That's what I wanted to find out.

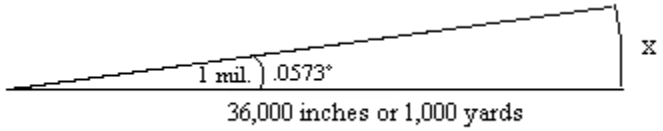
The Derivation of the Range Estimation Equations

To help derive the equation **(G)** above, I first want to enlarge the "triangle" that we have been using. I'm doing this so I can have the height of the target and the distance to it in yards, which is the form that the most simplified mil equation is usually in (see **G** above).

Now, if 1 mil = 3.6 inches at 100 yards, then at 10 times that distance, or at 1,000 yards, 1 mil = 36 inches. Don't believe me? Let's do our trigonometry again.

Still using 1 mil, but looking out at 36,000 inches or 1000 yards:

Fig. 8



1) $\text{Tan } \theta = \frac{\text{opposite}}{\text{adjacent}}$ **2)** $\text{Tan } .0573° = \frac{x}{36{,}000 \text{ in.}}$ **3)** $36{,}000 \text{ (Tan } .0573) = x$

(NOTE: the tangent of .0573 is .001)

4) $36{,}000 \text{ (}.0001) = x$ **5)** $x = 36$ inches

(H) Therefore, **1 mil at 1000 yards equals 36 inches, or 1 yard**.

So let's look at this tangent function without any numbers put in it.

1) $\text{Tan}(\theta \text{ in mils}) = \frac{\text{opposite (height of target)}}{\text{adjacent (distance to target)}}$

or in another easier to read form:

2) $\text{Tan}(\theta \text{ in mils}) = \frac{\text{height of target}}{\text{distance to target}}$

(To make it easier in the following math, let's use "D" equals the **"**distance to the target" and "H" equals the "height of the target". Also, remember that as of right now, the angle "θ" is still measured in "mils").

I want to cross multiply to solve for "D", the distance to the target.

3) $\text{Tan}(\theta) = \frac{H}{D}$

4) $D(\text{Tan}\,\theta) = H$

5) (I) $D = \frac{H}{\text{Tan}(\theta)}$ or (with "D" on the right hand side) **(I)** $\frac{H}{\text{Tan}\,\theta \text{ (in mils)}} = D$

The Tangent function works easier for things written in degrees, therefore we need to change the angle "θ" from **mils** to **degrees** (which we'll do later, but for now, just assume we already converted it). Now the equation (**I)** above looks like this:

$$\frac{H}{\text{Tan}\,\theta \text{ (in degrees)}} = D$$

Let's plug in some numbers and watch what happens. Let's say the height of an object is 1 yard, and we're reading 1 mil on our scope. What is the distance to the target?

Remember from **(C)** on page 4, 1 mil is equal to .0573 degrees, so converting mils to degrees, we can rewrite equation **(I)** above as:

1. $\frac{1}{\text{Tan}(1 \text{ mil})} = D$ **rewritten in degrees** = $\frac{1}{\text{Tan}(.0573°)} = D$

2. On the calculator, the tangent of .0573 is equal to .001, which can be rewritten as 1/1000.

3. Now the equation becomes:

$$\frac{\frac{1}{\frac{1}{1000}}}{} = D$$

Using algebra, multiplying be the reciprocal of the denominator, this now can be rewritten as:

$$\frac{1 \times 1000}{1} = D, \quad D = 1000 \text{ yards}$$

Therefore the distance to this target with a height of 1 yard, measured at 1 mil on my scope is 1000 yards, just like we saw in **(H)** from the top of page 9.

Now here is where it gets interesting. Guess what would happen if I measured 2 mils on my scope. 2 mils converted to degrees is 2 x .0573° = .1146°. Guess what the tangent of (.1146) is? The Tan (.1146°) = .002, or 2/1000. I can now rewrite equation **(I)** page 9 as:

$$\frac{1}{\text{Tan (2 mils)}} = D = \frac{1}{\frac{2}{1000}} = D \text{ which equals } \frac{1 \times 1000}{2} = D: \quad D = 500 \text{ yards to the target}$$

So if I measured my 1 yard high target at 2 mils, then the target would be 500 yard away.

Guess what the Tangent of 3 mils equals? Yup, you guessed it: 3/1000. i.e. (3 x .0573) = .1719. The Tan (.1719) =.003, or 3/1000. Are you starting to see a pattern here?

Even the Tangent of fractions of mils, say 3.25 mils = (3.25 x .0573) = .1862. =
Tan (.1862) = .00325 = 3.25/1000

And it goes on and on like this:

Tan (4 mils) = Tan (4 x .0573) = Tan (.2292) = .004 = 4/1000

Tan (5 mils) = 5/1000

Tan (6 mils) = 6/1000

•

•

.

Tan (25 mils) = 25/1000 etc. etc.

Let's examine what's going on. In the examples above, the tangent of the mils i.e. (1 mil, 2 mils, 3.25 mils etc.) turns out be a great, easy to work with, whole fraction, mainly 1/1000, 2/1000, 3.25/1000 etc. So equation **(I)** on page 9: (1) After **converting the "mil"**

angle to degrees, (2) then **taking the tangent of that angle**, (3) and **putting it in the denominator** of the equation where it belongs, is going to look like this:

$$\frac{H}{\frac{x \text{ mils}}{1000}} = D$$ **(Whatever mils you're reading is always over 1000)**

(See **Appendix A** for a different intuitive explanation of why mils is always over 1000)

After simplifying, it will look like this:

$$\frac{H \ 1000}{x \text{ mils}} = D$$ (where x = the number of mils).

Again, equation **(I)** on page 9 that was in the form:

$$\frac{H}{\text{Tan } \theta \text{ (in mils)}} = D$$

First goes to this:

$$\frac{H}{\text{Tan } \theta \text{ (converted to degrees)}} = D$$

Then this after taking the tangent of "θ":

$$\frac{H}{\frac{x \text{ mils}}{1000}} = D$$

And then this after simplifying:

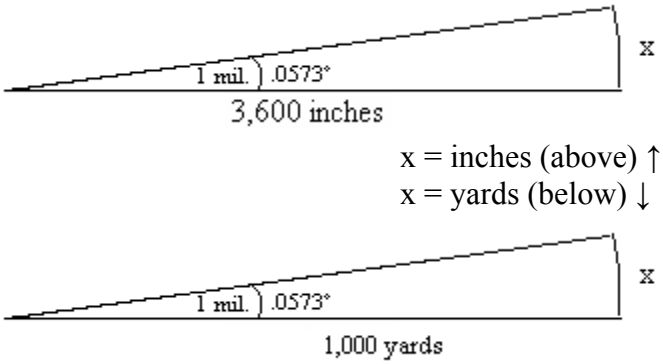
(J)

$$\frac{H \ 1000}{x \text{ mils}} = D$$ Which is the **Distance Equation using Mils** (like "G" on page 8).

(Where **H** = the **height** of the target in **yards**; "**x** mils" = the **number of mils** read on the scope; and **D** = the **distance** to the target in **yards**).

Now something interesting here needs to be mentioned. I have been using yards as the height of the object, but I also could have used inches, meters or whatever units I wanted to use. If you look at Fig. 9 below, (using the same triangle we used earlier), whatever units the "distance" portion of the triangle is in (the adjacent part), that is the same units that the "x" height portion of the triangle will be in (the opposite part). Or to put another way, whatever units the height "x" is in, the distance to it will be in the same units (i.e. inches, yards, meters, etc.).

Fig. 9



So in the equation: $\frac{H\ 1000}{\text{mils}} = D$, whatever units you are measuring the height "H" in, (x in the picture above), the distance to the target "D", will also be in the same units.

Example: $\frac{H\ (\textbf{meters})\ 1000}{\text{mils}} = D\ (\textbf{meters})$

Or, using the equation like we normally do, **whatever units you measure the "height" of the object in, the "distance" to it will be in the same units.**

Now, knowing the height of an object in inches might be reasonable, and in fact preferable, but getting the distance to it also in inches isn't.

For example: a 29 inch tire measured at 2 mils is by our equation:

$$\frac{29\text{ in. x }1000}{2\text{ mils}} = 14{,}500 \text{ inches to the target.}$$

How the heck far is that?

Well, 14,500 inches/36 inches per yard = 402 yards. 402 yards is much more comprehendible than 14,500 inches.

So let's make the equation more workable for us with units we are comfortable with. It is sometimes easier and more practicable to know the height of an object in inches, like a tire, or a head, but it's not that practicable to get the distance to it also in inch's, which our present equation does. So let's have the equation let us use **inches for the height** of an object but have it give us the **distance to it in yards**.

We need to convert the "H" part of equation **(J)** from **yards to inches**. The way we do that is by dividing by 36. Why? Well, take a 36 inch object and divide by 36. What do you get? 1…or more accurately, 1 yard. How about a 72 inch object, like a persons

height: 72/36 = 2 yards. Get it? **H/36 converts inches to yards**. So our mil distance equation **(J)** on page 11 now becomes (with "**H" still measured in inches**):

$$\frac{\frac{H}{36}}{\text{x mils}} = D = \frac{H\ \frac{1000}{36}}{\text{x mils}} = D = \frac{H\ 27.78}{\text{x mils}} = D$$

Notice: The left-hand sides of the equations in the steps above are still in **yards** even though we are using **inches** for the height of the object (because we divided "H" by 36). Like we talked about before, the right hand side of the equation, "D", will also be in the same units, which are **yards** in this case.

Putting labels back on, our equation looks like this:

(K)

$$\frac{\text{H (inches)}\ 27.78}{\text{mils}} = \text{Dist (yards)}$$

So there it is. The "distance equation using mils" derived and explained.

How to derive the MOA Equation

If you have a scope like I do that has a **moa** reticle, then I need a "distance to target" equation that uses "moa" instead of "mils". In the distance equation **(K)** above, I need to convert mils to moa. Remember from **(D)** on page 4, **1 mil = 3.438 moa**. Just like above when we converted inches to yards by doing H/36, I want to have the "mils" portion in the denominator converted to "moa". So I **divide moa by 3.438** to get equation **(K)** above expressed with **moa** in the denominator.

For example:

If I measure a target 3.438 moa on my scope (I know I can't really measure that, but we're talking theoretically here) and then divide by 3.438, I get 1. (You would get 1 mil measuring the same object if using your mildot scope). If I measured an object 6.876 moa on my scope, then 6.876/3.438 = 2. (You would be measuring 2 mils on your mildot scope). So now the "distance equation" looks like this after substituting **moa/3.438** for **mils** in the denominator of the "mils distance equation" (**K)** above:

$$\frac{H \times 27.78}{\frac{\text{moa}}{3.438}} = D = \frac{H \times 27.78 \times 3.438}{\text{moa}} = D = \frac{H \times 95.5}{\text{moa}} = D$$

So the "distance equation using **moa"** is (with labels back on):

$$\textbf{(L)} \qquad \frac{\textbf{H (inches) x 95.5}}{\textbf{moa}} = \textbf{D (yards)}$$

(See **Appendex B** for an alternate way to derive this equation.)

Some simplify it to: $\frac{\text{H (inches) x } \mathbf{100}}{\text{moa}}$ = D (yards), which makes it real easy to use.

Let's see if it works. Remember from **(F)** on page 6, there are 1.047 inches per minute of angle (moa) at 100 yards. If I draw a line on a target at 100 yards that is 1.047 inches long, then looking through my scope, I should see that 1.047 inch line exactly between my 1 moa tics on my reticle. Plugging those numbers in the equation, I get:

$$\frac{\text{1.047 (line I drew) x 95.5}}{\text{1 moa (on my scope)}} = \text{99.99 yards or (100 yards rounded)}$$

Exactly what I should be getting. In the equation above, if I used the constant 100 instead of 95.5, then I would have gotten 104.7 yards. Close enough. We can all multiply by 100 in our head, but how many can multiply by 95.5. So a lot of shooters just use:

$$\frac{\textbf{H (inch's) x 100}}{\textbf{moa}} = \textbf{D (yards)}$$

Note: Be careful though, at greater distances, the discrepancy between 95.5 and 100 as the constant could change the result enough to be critical to the accuracy of your shot.

So there you have it. The **mil and moa distance equations** explained and derived.

I hope this paper gives you a better understanding of exactly what **mils** and **moa** are, and a better understanding of their **distance equations**. I also hope that it makes them easier for you to use and apply. Now, you can brain dump all this math and definition stuff and just use them like you always did.....but with a little better knowledge.

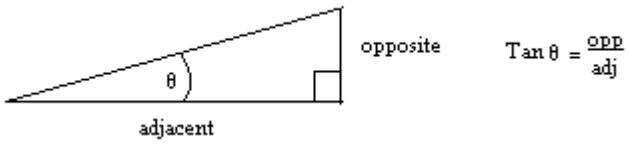
Good Shooting,

Robert J. Simeone

Appendix A

Why is the Tangent of "Mils" always equal to **"x"mils/1000**?

Intuitively you can see why this must happen. The tangent of an angle of a right triangle is the ratio of the opposite side divided by the adjacent side i.e. Tan (θ) = opp/adj.



A "mil" is $1/1000^{th}$ of a radian (it can also be thought of as $1/1000^{th}$ of the radian arc). The angle "θ" (in mils) chops the **arc,** the opposite part, into parts of 1000. For example, a 1 mil angle chops the arc into $1/1000^{th}$ of its length; 2 mils chops it into $2/1000^{ths}$ of its length; 3.25 mils chops it into $3.25/1000^{th}$ of its length and so on and so on (Fig.10 below). The **radius**, or the adjacent part, is still the same "whole" length (not chopped up) and equal in length to the "whole" arc length (Fig.11 below).

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Fig. 10

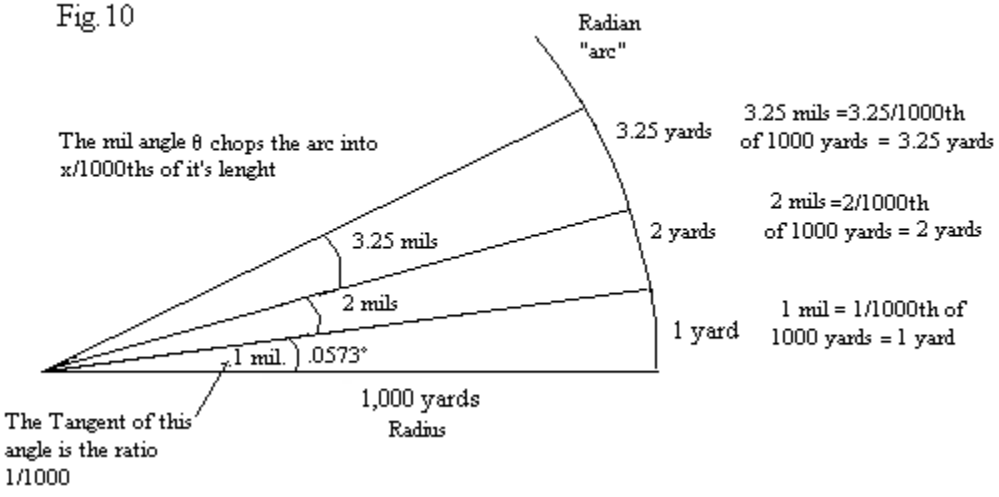
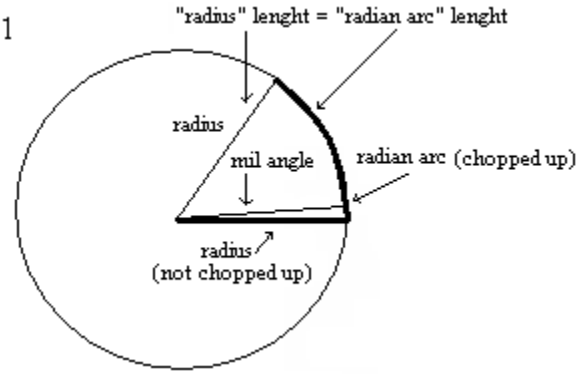


Fig. 11



Therefore, the **ratio of the opposite side to the adjacent side (the definition of "tangent")** is always in the form:

(M)

$$\text{Tan } (\theta \text{ in "x" mils}) = \frac{\text{Opposite side in } \textbf{"x"}1000^{\text{ths of the adjacent sides length}}}{\text{Adjacent side (whole length } \textbf{"W"})}$$

Where "x" is the number of mils you're reading and "W" equals the "whole" entire length of the adjacent side (which is really the radius and/or the distance to the target).

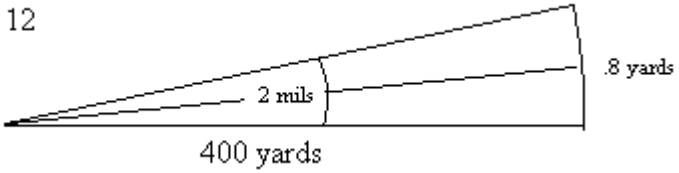
Therefore:

$$\textbf{Tan (θ in "x" mils)} = \frac{\frac{x}{1000}}{W} \quad W = \frac{x}{1000} \quad W \frac{1}{W} = \frac{x}{1000} \frac{\cancel{W}}{\cancel{W}} \frac{1}{} = \frac{\mathbf{x}}{\mathbf{1000}} \quad .$$

That would mean simply, for example, that: $\text{Tan (2 mils)} = \frac{2}{1000}$.

Let's look at an example to help make this a little easier to understand:
The range to a target is 400 yards, and you're reading 2 mils (Fig.12 below).

Fig. 12



Referencing equation **(M)** above then, the **Tan (2 mils)** =

$$\textbf{Tan (2 mils)} = (\text{opp. side in 2/1000ths of adj. side}) \rightarrow \frac{2}{1000} \text{ x } 400 \quad (\text{adj. side whole length}) \rightarrow 400 = \frac{2}{1000} \frac{\cancel{400}}{\cancel{400}} \frac{1}{} = \frac{\mathbf{2}}{\mathbf{1000}} \quad .$$

or, a little easier to visualize, look at Fig.12 again:

2 mils = $2/1000^{\text{ths}}$ of 400 = $\frac{2}{1000}$ x 400 = .8 yards for the opposite side length.

$$\text{Tan (2 mils)} = \frac{\text{opp}}{\text{adj}} = \frac{.8}{400} = .002 = \frac{2}{1000} \quad .$$

As you can see, the Tangent of "x" mils" is always equal to "x" mils over 1000 (where "x" is the number of mils, i.e.1, 2, 3.25 etc.). Since the tangent of the "mils" is in the denominator of the equation (see **(I)** on page 9), the denominator will always be in the form $\frac{\text{"x" mils}}{1000}$ and the equation will be: $\frac{H}{\frac{\text{x mils}}{1000}} = D$ (just like at the top of page 11).

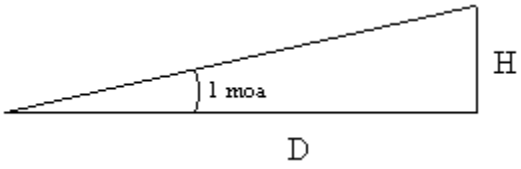
Simplified it looks like this: $\frac{H\ 1000}{x\ \text{mils}} = D$ (like **(J)** on page 11)

What we did this time was just use a different method to analyze why the equation looks like it does. We did it without converting mils to degrees and without using the tangent function of our calculator.

Appendex B

We figured out earlier how to derive the "moa distance" equation by substituting **moa/3.438** for mils in the denominator of the "mil distance" equation (see page 13). Here we are going to derive the "moa equation" from scratch like we originally did with the mil distance equation (starting on page 8).

Look at the figure below:



$\text{Tan (1 moa)} = \frac{H}{D}$ **(N)** $D = \frac{H}{\text{Tan (1 moa)}}$ Remember, 1 moa = $1/60^{th}$ of a degree.

Tan (1/60°) = Tan (.016667) = **.0002908882 = Tan (1 moa).**

Let's start looking for a pattern. What if the angle in the picture above was 2, 3 or 4 moa?

Tan (2 moa) = Tan (2/60°) = Tan (.03333333) = .0005817765
Tan (3 moa) = Tan (3/60°) = Tan (.05000000) = .0008726648
Tan (4 moa) = Tan (4/60°) = Tan (.06666667) = .001163553

At first it might not be obvious, but each of the tangents of the moa's above (2, 3, and 4) is really just a multiple of .0002908882, which is the tangent of 1 moa. That is, the tangent of 2 moa can be thought of as 2 x .0002908882 = .0005817765. The tangent of 3 moa can be thought of as 3 x .0002908882 = .000876647 etc. etc. Therefore we can rewrite the equation **(N)** above as:

$D = \frac{H}{x\ (\text{Tan 1 moa})}$ (where x = some moa value).

For example, if the moa value is 2, then:

$D = \frac{H}{\text{Tan (}\mathbf{2}\text{ moa)}}$ can be rewritten as $D = \frac{H}{2\ (\text{Tan }\mathbf{1}\text{ moa})} = D = \frac{H}{2\ (.0002908882)}$.

Therefore, it follows that equation **(N)** on page17 can now be rewritten as:

(O)

$$D = \frac{H}{x\ (.0002908882)}$$.

(where "x" is some moa value, and .0002908882 = Tan 1 moa)

Note: .0002908882 can be rewritten as and is equal to $\frac{2.908882}{10{,}000}$. Therefore equation **(O)** above can be rewritten as: $D = \frac{H}{x\ \frac{2.908882}{10{,}000}} = \frac{H\ \ 10{,}000}{x\ \ (2.908882)} = \frac{H\ \ 3437.75}{x} =$

(P) $D = \frac{H\ \ 3437.75}{x}$ Therefore the distance to a target using **moa** values is the height of the target multiplied by the **constant 3437.75** divided by the moa value "x". Remember from before (page 12) that the distance will be in the same units as the height of the target i.e. if the height is in inches, then the distance to it will also be in inches; if the height is in yards, then the distance to it will also be in yards. So let's make this equation more user friendly like we did earlier with the mil distance equation on pages 12 and 13. In the equation **(P)** above, let's use **inches** for the height "H" of the target, and let's get the distance "D" to the target in **yards**. Remember from page 13, H/36 converts inches to yards. Therefore our equation **(P)** above now becomes:

$D = \frac{\frac{H\ \ 3437.75}{36}}{x} = \frac{H\ \ \frac{3437.75}{36}}{x} = \frac{H\ \ 95.5}{x} = D$ Just like **(L)** on page 14, where "H" is in inches, "D" is in yards and "x" is a moa value.

There it is, the equation for the "distance to a target using **moa"**, derived a little differently from how we did it earlier on pages 13 and 14.

Note: Look at the "3437.75" in equation **(P)** above. Rounded, it is 3438. Does that number look familiar? (Look at **(D)** on page 4). Now look at the **mil** distance equation, which is: $\frac{H\ 1000}{\text{mils}} = D$. Now compare it to the **moa** equation **(P)** above: $\frac{H\ 3438}{\text{moa}} = D$

They look awfully familiar. The **moa equation is exactly the same as the mil equation** except that it is multiplied by 3,438 instead of 1,000. That's because **1 mil = 3.438 moa** (**D**, page 4). So it only makes sense that the moa equation is larger than the mil equation by a factor of 3.438 (1000 x **3.438** = 3438).