

Mil-dots and Minutes-of-angle, From a Technical Perspective

If you've always wondered what those little dots are for on a military rifle scope's reticle (cross-hairs), then look no further. I hope to explain, in a clear and concise fashion, how the mil-dot reticle works and also what "minute-of-angle" means.

Minute-Of-Angle

The term "minute-of-angle" (MOA) is used regularly by target shooters at the range, but is probably understood, thoroughly, by few (the same goes for mil-dots). Defined loosely, one MOA = 1" @ 100 yards; so, if you shot your rifle 5 times into a 100-yard target and every shot went into a one-inch circle you had drawn on the paper, then your rifle could be said to shoot 1 MOA. Likewise, if every shot goes into a two-inch circle at 200 yards, then you're shooting 1 MOA. A 10-inch group at 500 yards would be 2 MOA.

Now for the fun part. There are 360 degrees in a circle. Each degree can be broken down further into minutes. There are 60 minutes in a degree. Likewise, there are 60 seconds in a minute. Now, to figure out the distance subtended by 1 minute at any particular distance, we need merely to plug those two values into a simple trigonometric equation. The tangent function fits the bill nicely. Here's the equation:

$\tan(\text{angle}) = \text{distance subtended} / \text{distance to the target}$ (units must be consistent--e.g., 1/36 of a yard [1"] divided by 100 yards)

Now, we know the angle (1 minute or 1/60 of a degree) and we know the distance to the target (100 yards), but we need to figure out the actual distance subtended at the target (i.e., is 1 MOA actually 1" @ 100 yards?). What we need to do is solve for "distance subtended." Here's our final equation:

$\tan(\text{angle}) * \text{distance to the target} = \text{distance subtended}$

Make sure your calculator is in "degree" mode (as opposed to "radian" or "gradian") and type in 1/60 (for degrees) and hit the "tangent" button. Then multiply that by 100 yards. This should give you the distance (in yards) subtended at 100 yards. Multiply this by 36 to get inches. The answer should be:

1.047197580733"

This is just a hair over the commonly quoted "one inch." At 1000 yards, this would be almost 10 1/2 inches. Apparently, it is just a coincidence that 1 MOA happens to be REALLY close to 1" @ 100 yards. It is, however, quite convenient.

The Mil-Dot

The "Mil" in "Mil-Dot" does not stand for "Military"; it stands for "milliradian." The radian is a unitless measure which is equivalent, in use, to degrees. It tells you how far around a circle you have gone. $2 \text{ PI radians} = 360 \text{ degrees}$. Using 3.14 as the value of PI, 6.28 radians take you all the way around a circle. Using a cartesian coordinate system, you can use "x"- and "y"-values to define any point on the plane. Radians are used in a coordinate system called "polar coordinates." A point on the plane is defined, in the polar coordinate system, using the radian and the radius. The radian defines the amount of rotation and the radius gives the distance from the origin (in a negative or positive direction).

ANYWAY, the radian is another measurement of rotation (the degree/minute/second-system being the first). This is the system used in the mil-dot reticle. We use the same equation that we used before, but, instead of your calculator being in "degree" mode, switch it to "radian" mode. One milliradian = 1/1000 (.001) radians. So, type .001 into your calculator and hit the "tangent" button. Then multiply this by "distance to the target." Finally, multiply this by 36 to get inches subtended at the given distance. With the calculator in "radian" mode, type:

$\tan(.001) * 100 * 36 = 3.600012"$

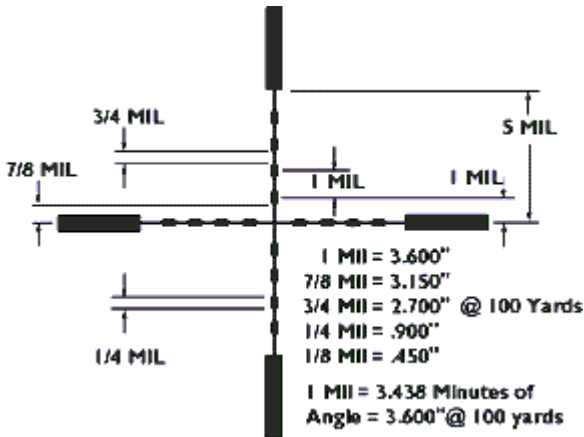
So, one milliradian is just over 3.6 inches at 100 yards. If we extrapolate, two milliradians equal about 6 feet at one-thousand yards. You'll see the importance of this, shortly.

The Mil-Dot Reticle

The mil-dot reticle was designed around the measurement unit of the milliradian. The dots, themselves, were designed with this in mind and the spacing of the dots was also based upon the milliradian. This allows the shooter to calculate the distance to an object of known height or width. Height of the target in yards divided by the height of the target in milliradians multiplied by 1000 equals the distance to the target in yards. For example, take a 6-foot-tall man (2 yards). Let's say that the top of his head lines up with one dot and his feet line up four dots down. So: $(2/4) * 1000 = 500$ yards away. This same technique can be used to estimate lead on a moving target or to compensate for deflection on a windy day.

The distance from the center of one dot to the center of the next dot is 1 milliradian. We are told (by the folks at Leupold) that the length of a dot is 1/4 milliradian or 3/4 MOA (Given this much information, one can determine that the distance between dots is 3/4 milliradian.).* I use the term "length" because the mil-dot is not round. It is oblong. The "dots" on the vertical crosshair run oblong in the vertical direction. The dots on the horizontal crosshair run oblong in the horizontal direction (i.e., they are lying on their sides). The width of each dot is an arbitrary distance and is not used for any practical purpose. Like a duplex reticle, the mil-dot reticle is thicker towards the edges and uses thin lines in the middle where the dots are located and the crosshairs cross. The distance between the opposite thick portions is 10 milliradians.

*NOTE: 1/4 milliradian = .9" and 3/4 MOA = .785", so, obviously, a mil-dot cannot be both 1/4 milliradian and 3/4 MOA. I called Premier Reticles (they make Leupold's mil-dot reticles) and got an explanation: the dots on their mil-dot reticles are 1/4 mil. They are not 3/4 MOA. Apparently, they (Leupold?) just figured that more shooters understand MOA than milliradians, so they just gave a figure (in MOA) that was close, but not super precise. You can contact [Premier Reticles](#) via e-mail and request literature or ask questions.



Summary

To use a mil-dot reticle effectively, all one need remember is that the distance between dot centers is 36" at 1000 yards. This lets you determine the range of a target of known size. At that point, you can dial the scope in for proper elevation OR use the dots to hold over the proper amount. The dots on the horizontal crosshair can be used to lead a target (if you know the range to the target, then you'll know the distance between dots, and thus the distance to lead) or to compensate for deflection.

All you ever wanted to know about mil-dots and minutes-of-angle, and then some!