

# OPERATIONAL ASPECTS OF REFLECTORLESS EDM TOTAL STATIONS

**JOSEPH V.R. PAIVA**  
**Trimble**  
**7403 Church Ranch Blvd., Suite 100**  
**Westminster, CO 80021**  
**(720) 887-4260**  
**email: joseph\_paiva@trimble.com**

## ABSTRACT

Reflectorless EDMs have been available in total stations and as stand-alone devices for approximately a decade. In the last two years, a new crop of reflectorless EDM total stations has appeared on the market. While there are differences between them, even with respect to the embodiment of the EDM technology, there are many similar aspects to their use in the field. The reflectorless EDM offers new opportunities to surveyors, but it demands knowledge of the technology, not only to gain the benefits of efficiency and speed, but also to ensure that correct measurements are being made. The discussion centers on comparing and contrasting the use of the reflectorless EDMs as compared with the more common phase resolving types. Advantages in using the reflectorless EDMs are presented. Shortcomings arising from inadequate understanding of the technology are also discussed.

## BIOGRAPHY

Joseph V. R. Paiva, is director of business development for the Engineering & Construction Division of Trimble Navigation Ltd. His previous assignments at Trimble have included senior scientist and technical advisor for Land Survey research and development and vice president and general manager of the Land Survey group. Previously, Paiva was vice president and a founder of Sokkia Technology, Inc., where he guided the development of GPS- and software-based products for surveying, mapping, measurement and positioning. He has also held senior technical management positions in The Lietz Co. and Sokkia Co. Ltd., of Tokyo, Japan. Dr. Paiva was also a professor of civil engineering at the University of Missouri-Columbia, and a partner in a surveying/civil engineering consulting firm. He is a Registered Professional Engineer (PE), Registered Land Surveyor (LS), and has more than 25 years experience working in civil engineering, surveying and mapping.

## INTRODUCTION

EDM measurement has been with us so long that we have come to expect it as unvarying. Reflectorless EDM measurement changes that. While still called “EDM” reflectorless EDM

quite distinctly changes the physical processes that occur during a measurement. For the surveyor, being aware of these differences is critical and key to successful measurement. Capitalizing on the extensions to what we have thought of as the EDM measurement process requires a basic understanding of how reflectorless EDM measurements are done.

The basic difference between conventional EDMs and reflectorless EDMs is that reflectorless EDMs may be used without a retroprism. This seems basic enough. But the number of surveyors using reflectorless EDM who complain when that waving branch in the line of sight causes an erroneous result indicates a lack of understand of the physics of the measurement.

## WHAT REFLECTORLESS EDMS DO

Without going into great detail, the basic method of reflectorless EDM is that many individual pulses of light are emitted, each of relatively high energy when compared with phase resolving EDMs. For example the pulses in the Trimble 5600 DR<sup>+</sup> are at the 12W level, whereas most phase resolving EDMs are at the tens of mW level. Because of the higher energy level, more is reflected off non-prism surfaces and is detectable when it returns to the source of the emitted light. The detectors in the EDM then process the pulse, compare it with the emitted pulse, and determine the time of flight and from that the transited distance.

Just as with phase resolving EDMs, the infrared light is emitted in a cone shaped pattern, i.e. it diverges as it goes further away from the emitting source. In the Trimble 5600 DR<sup>+</sup> for instance, the beam divergence is 0.8 mrad (8cm per 100m). The reason beam divergence is important is that the surveyor should not assume that a single point of light with no dimension “pinpricks” the target at the location of the intersection of the crosshairs. Instead, a roughly circular pattern is “splashed” on the surrounding area. Energy is then return from the entire splashed “footprint.”

It is because of this characteristic that the reflected pulse waveform often is quite distorted with respect to the emitted pulse. However, it should be remembered that even if the target area is a plane and normal to the emitted pulse, that the surface characteristics of the target will distort the pulse to make it different from the emitted pulse.

### **Single Plane Surfaces**

When measurements are made with reflectorless EDM to plane surfaces, the returned pulse is distorted to parallel the plane. I.e. the pulse is least deformed if the plane is normal to the axis of the EDM pulses. If not normal, then the parts of the cone of light which strike the closest part of the target plane will reflect light first and those which strike the furthest part of the target plane will reflect the light last. In general, the measurement made to the plane will be accurate as long as there is not a huge disparity in infrared reflectance over the splash area.

### **Multiple Plane Surfaces**

“Multiple plane surfaces” refers to the splash area covering more than one distinct plane, the centroid of each splash sub-surface being at a different distance from the emitter. In this case, if the separation between the foremost and rearmost surfaces does not exceed one-half of the pulse length (in the case of the 5600 DR<sup>+</sup>, the pulse length is 1.3m, corresponding to a single pulse time of 4.5 nsec), the instrument will not be able to recognize that there are different surfaces. A

weighted average of the pulse return times will be used, with the brightest, if there are any, adding more weight. If the surfaces are all of equal reflectivity, then the surfaces most “illuminated” by the splash area will tend to dominate the result indicated by the EDM system.

When the surfaces are separated along the measurement axis by more than one-half of the pulse length, it is possible that the signal processing techniques in the instrument will recognize two or more pulses as good candidates for computing the measurement with. Since the instrument is designed to give one result, the instrument should indicate that there is ambiguity in the returned signals. In the case of the 5600 DR<sup>+</sup>, a possible solution for the surveyor is to use the built-in function that allows the selection of a range within which the resulting measurement will fall, so that all results falling outside the range will be discarded.

### **Combinations of Plane Surfaces**

A special case to note is the plane surface normal to the emitted light combined with one or more plane surfaces that lie at oblique angles to the emitted light. Again, the surface normal to the light will reflect the most light back to the instrument, even if the other surfaces are identical in every other way to the normal surface. Thus the normal surface will tend to dominate the result determined by the EDM system.

### **Curved or Irregularly-shaped Surfaces**

The best description of the resulting distance measurement when measuring to curved or irregularly-shaped surfaces is that the reflected pulse waveform will represent the integration of the splashed surface(s), with weighting being applied based on the reflectivity. Keep in mind that a smooth surface tube painted white one foot in diameter and 200 meters away from the instrument will be illuminated with a 16cm (approximately half-foot) spot.

The intuitive result for the measurement that one might hypothesize would be one that falls approximately one-third inside the illuminated curved surface, when visualized in plan view. In practice, it turns out that the distance will be very close to that measured to the surface of the tube closest to the instrument. This occurs because of the variation in reflectivity that happens because of the angle of incidence. The surface of the tube normal to the incident pulses exhibit a very high percentage of returned light, whereas the parts not normal to the incident pulses tend to reflect maximally in some direction other than back to the instrument. Thus it is important to remember that the physics of reflection must be considered when judging the reflectivity of an apparently homogeneous surface.

## SPECIAL SOFTWARE FUNCTIONS

Special software functions are often provided with reflectorless EDM total stations that may not be provided with their phase resolving counterparts. Many of these are intended to avoid erroneous results that may occur due to some of the scenarios described above. Some take advantage of the inherent capabilities of the reflectorless advantage and provide functions not available with the phase resolving EDM.

### **Corners**

Surveying the position of the corners of objects such buildings are problematic even with phase resolving EDMs. The care that must be exercised in positioning the prisms, and the fact that the prisms cannot be easily placed such that their plumbing points are on the vertical lines defining the corners have led to special software solutions. Reflectorless EDMs have different issues to be resolved when positioning corners.

Corner Measurement by Plane and Piercing Ray: Measuring inside or outside corners of objects such as buildings involves splashing the incident pulses more or less on the two surfaces when an inside corner. If an outside corner, often only one surface is illuminated, though it is also feasible to illuminate both surfaces. In the case of the Trimble 5600 DR<sup>+</sup>, a special software function enables the instrument operator to take two readings along one of the walls (surfaces) to define the plane. Then by merely sighting the corner without taking a distance reading, the intersection of that ray with the plane is computed to determine the position of the corner. This program works with both inside and outside corners.

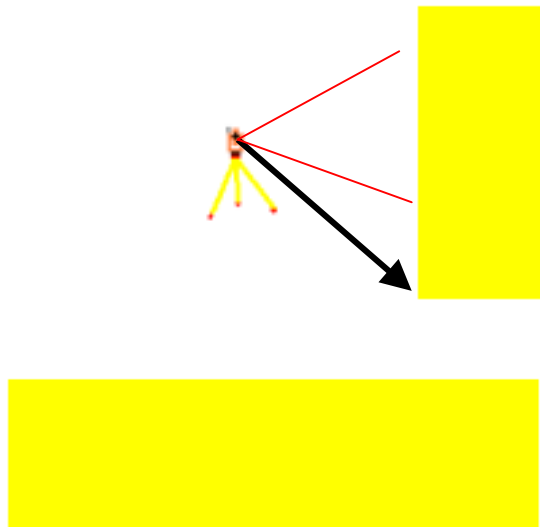


Figure 1: Outside Corner Measurement with Two Observations to Determine the Plane

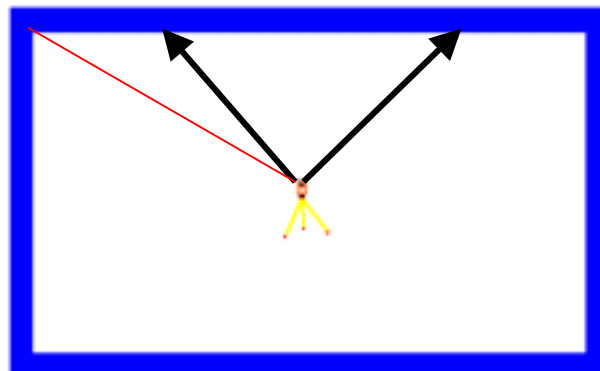


Figure 2: Inside Corner Measurement with Two Observations to Determine the Plane

The software allows measurement to more than one corner. Thus, after establishing the plane with the two initial observations, as in the figure below, it is possible to sight both corners as angle-only observations to determine the piercing points of the plane.

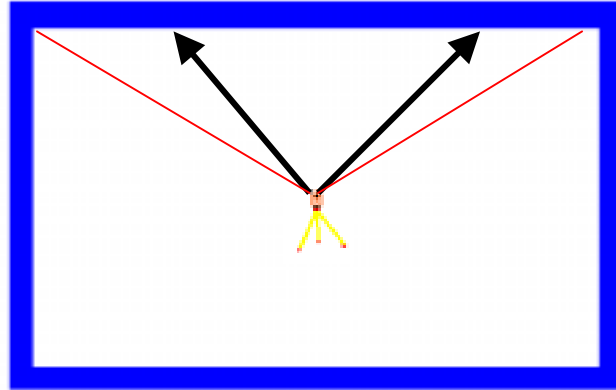


Figure 3: Determining Multiple Intersecting Points after Establishing the Plane

Corner Measurement by Plane and Taped Orthogonal Distances: In a manner similar to a software solution devised for phase resolving EDMs, corners may also be located by first measuring two points on one of the surfaces. Assuming then that the all the other corners to be located are formed by surfaces parallel or perpendicular to this surface, but not visible from the instrument station, the lengths of each wall may be taped.

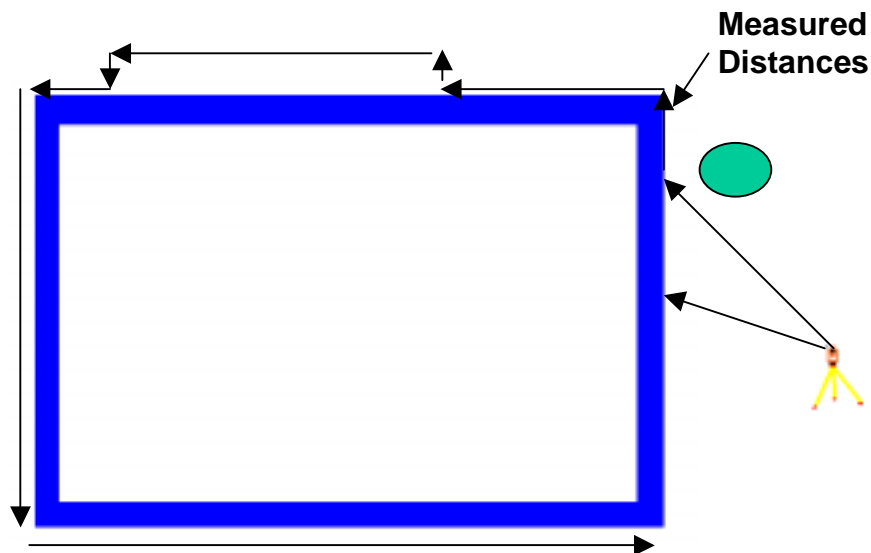


Figure 4: Corner Measurement by Determining Plane and Orthogonal Taping

Corner Determination by Locating Two Intersecting (non-orthogonal) Planes: The most sophisticated corner solution software application is an extension of the first. By taking two measurements each, the two intersecting planes that define the corner are located in space. This

may be an inside or outside corner, and the angle of intersection can be different from  $90^\circ$ . As soon as the four base measurements are taken, the software extends the plane and locates the corner of interest.

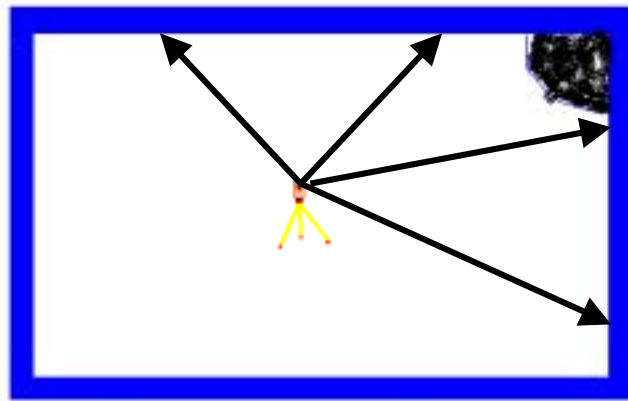


Figure 5: Locating Corners by Locating the Two Intersecting Non-orthogonal Planes

### Locating Objects with Circular Cross-sections

When locating objects such as trees and utility poles, surveyors make many compromises in either accuracy or the effort expended to locate them. A distinct advantage of reflectorless technology is that one can sight the apparent center of a cylindrical, vertical object to locate the ray along which the object's centerline lies. Simple trigonometry following an angles-only sighting to the left or right extremity of the object allows the radius to be computed. Then the position of the centerline can be computed and its radius or diameter logged as well. This function is also useful for determining the mapped position of objects that can't be reach easily such as tree crowns.

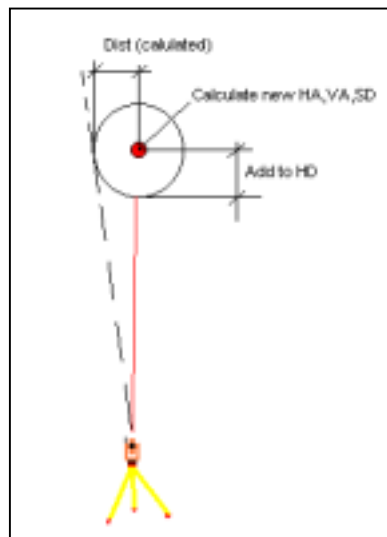


Figure 6: Locating Position and Diameter of Circular-cross-section Objects

## OTHER SPECIAL FEATURES

Special analytical processes are used to make measurements on the emitted and reflected waveforms to determine the time of flight and thus the distance. It is possible to make use of the statistical tools and statistics generated during the analysis to make the job of surveying more effective.

### **Standard Deviation-dependent Measurements**

Where measurements are difficult to make with precision or where precision is not required, it is possible to set the standard deviation that the final composite measurement must have. The instrument can then be started to measure. It will stop when its measurement reaches the required precision. When conditions don't allow even that value to be achieved, it informs the user.

### **Measurements with Reflectors**

It is still possible to use reflectors, whether glass retroprisms, plastic reflectors, reflective sheeting, or even reflective paint to make measurements to objects. Using such reflective materials can be used to advantage when desiring to measure long distances. For example the 5600 DR<sup>+</sup> can measure 5.5 km (3.4 mi) to a single prism. Another advantage is that the pulse returned from the reflective material is so "bright" in comparison to other "non-cooperative" material that may also be illuminated, that the reflected pulse from the non-reflective material is almost always ignored. It seldom even falls into the analogy of the weighted mean, so much is the difference in power in the signals. This relative difference in reflectivity should be understood. For example while using a mini-prism, concern has been expressed about the reflectivity of the rod person's jacket that may be reflective or have reflective stripes on it. Experiments to date have shown that the superior optical characteristics of the prism cause the reflected pulse from it to dominate and overpower the weaker signals from the jacket.

### **Selective Distance Ranges**

As previously discussed distance ranges can be set to prevent distances from being measured to other than the intended target. This can even be used when the case of the "waving branch" occurs. A key aid to this function is the reflectorless nature of the EDM. Quite often the surveyor does not know what range to specify. Many times it is possible to measure to an object near the desired object to quickly fix the desired range in software.

### **Use with Servo and Robotic Upgrades**

The use of servos with the reflectorless EDM enable time intensive and possible dangerous tasks such as measurement of spoil piles, unstable rock and soil faces, etc. be undertaken automatically. Users often take the automation a step further by automating the data analysis and reporting as well.

With robotic features, the instrument can be used initial with one person at the instrument to quickly locate objects that have vertical relief such as buildings, trees, utility poles and fire hydrants. By minimizing walking, it is potentially faster than either RTK or robotic surveying. However it rare than an entire survey or even most of it can be done with reflectorless EDM

alone. After completing the reflectorless portion of the survey, the surveyor can switch to robotic mode (or RTK GPS) and continue the one-person survey operation.

