EDM Without Reflectors

MATHIAS LEMMENS

A total station is an angle measuring device, also known as theodolite, integrated with an electronic distance meter (EDM). The integration provides the ability to measure angles and distances by the same instrument which gives the surveyor a leap in portability, convenience and speed since 1980. Today, total stations have a wide variety of capabilities and are extensively exploited in surveying, civil engineering and construction. EDM units employ electromagnetic (EM) energy for measuring the slope distance to a target point.

Two principles are in use: phase shift and pulse—also called time of flight—measurements. The EM energy may be emitted as infrared carrier signals, generated by a small solid-state emitter within the instrument's optical path and modulated as sine waves. The phase of the returning signal is compared to the phase of the emitted signal. This can be done with a precision at the millimetre level. However, the total number of full cycles is yet unknown and to obtain them multiple wavelengths are used. The other method uses laser pulses. The travel time of the pulse forth and back is measured and by multiplication with the speed of light and dividing the

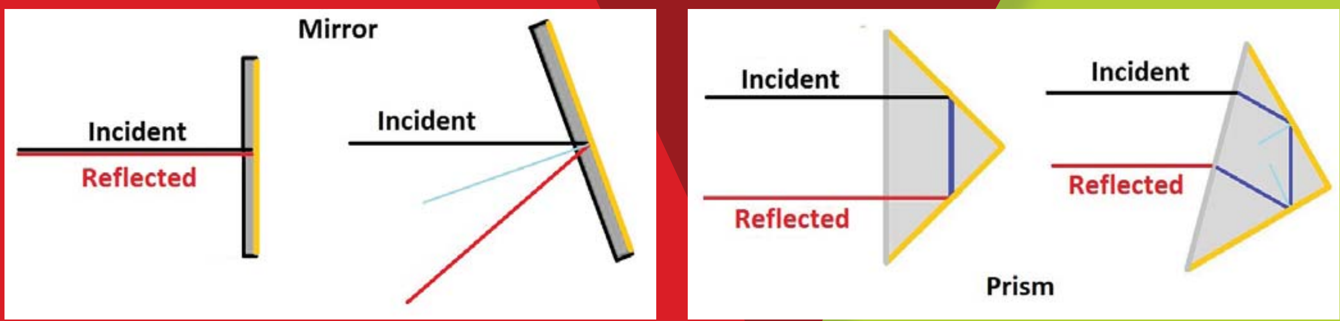

Figure 1: Reflection of a EM beam on a mirror (top left) and on a prism.
M. LEMMENS

Figure 2: A great variety of prisms are on the market.
M. Lemmens

result by two the distance is calculated. This is why the laser pulse method is also called time of flight (ToF). Some total stations combine both measurement principles in one and the same device. With a precision ranging from sub-mm to sub-cm level the phase shift method is the most accurate one, but its measuring range is limited to around 100m. ToF EDM units may measure distances up to 10km and even more, depending on atmospheric conditions and type of prism used, but their precision usually ranges from sub-centimetre to centimetre level while the accuracy is bad for short ranges.

Reflectorless

Reflectorless EDM has become standard in surveying. Today, up to 1 km can be bridged without using a prism eluding the need to access the target. The range depends on the strength of the emitted signal and the reflectivity and geometry of the target. Inaccessible objects or targets located at dangerous sites can thus be mapped easily. To detect returns from bare surfaces, i.e. using no prisms, requires laser pulses with a high energy level typically in the range of 1 to 20 watt. In contrast, most phase-based EDMs using prisms emit signals at a level of a few milliwatt. The EM signal will be reflected on any surface it meets.

The strength of the return will depend on how the incident signal interacts with the surface: the entire signal or a part of it may be reflected, absorbed or transmitted. Only reflected beams will reach the instrument and thus be of use, but one reflection is better than another. Ideally, a surface behaves as a diffuse reflector: reflections are of like strength in all directions and thus the energy level reaching the instrument is highest. But when behaving as a specular surface, which acts as a flat mirror, the reflection is deflected and little or no signal will be received (**Figure 1, left**).

Only when the mirror is perpendicular to the path most of the signal will reflect in the direction of the instrument. To overcome this issue surveyors often place reflectors on the target point consisting of three mirrors or reflective prism faces, which are mounted mutually perpendicular. Such reflectors push the beams back in the direction of the source, but shifted (**Figure 1, right**). Several prisms can also be combined to increase the reflected energy and so to increase the distance to be bridged. For example, with one prism a total station may have a reach of 3km, with three prisms 4km and with five prisms 5km. Prisms are used for both ToF as well as phase shift EDM units. Depending on application, the surveyor can choose from a large variety of prisms (**Figure 2**).

Since the signal may reflect upon any surface present in the line of sight, blunders may easily occur. For example, the signal may be reflected on a leaf that whirls through the line of sight. Another concern is beam divergence, i.e. the increase in beam diameter with distance from the source. The laser spot hitting the surface is not a point in the mathematical sense but will be a footprint with a certain size; the greater the distance, the larger the footprint. This may result in three types of errors.

Errors Due to Beam Divergence

The first error type is introduced by the target surface. Difference in surface characteristics of the target and its vicinity will cause that the waveform of the back scattered part of the pulse may be a distorted version of the emitted one, which impedes the resolve of the exact time the backscatter enters the instrument and thus affects accuracy. A second error type stems from a target that is located on a plane that is not perpendicular to the line of sight; the part of the plane that is closest to the instrument will reflect the beam first and the part farthest away last. The effect will be negligible when the reflectance characteristics of the plane are homogeneous: the reflected pulse will be elongated but will have everywhere the same signal strength enabling the resolve of the exact time the backscatter enters the instrument. When the reflectance changes within the footprint, the return pulse will be distorted and it will be hard to resolve the exact arrival time. Discontinuities in the vicinity of the target will induce time differences between the reflections of one and the same pulse, introducing a third error type. If the depth differences do not exceed one-half of the pulse length, the reflected pulse will be treated as stemming from one surface. Since the reflected pulse will be elongated with fluctuating signal strengths, the time of flight cannot be detected accurately.

One thing is for sure: how advanced a device may be, if not in the hands of a skilled person the output will be trash. ■

Mathias Lemmens gained a PhD degree from Delft University of Technology, The Netherlands, where he lectures on geodata acquisition technologies and geodata quality since 1984. He is an international consultant and the author of the book Geo-information—Technologies, Applications and the Environment published by Springer in 2011. He is working on a book on the processing and use of Point Clouds to be published in 2017.