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Trihedral rectangular ultrasonic reflector for distance measurements

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A trihedral rectangular reflector is made of Perspex, whose characteristic is that the reflecting ultrasonic beam follows an opposite direction from that of the incident beam. When the reflector is used as the 'target' for measurement, the distance derived is the distance between the transmitter and its top, regardless of its orientation, under certain limitations.

Keywords: ultrasonics, trihedral reflector, distance measurement

Ultrasonic instruments used for measuring distance through the air that use the pulse echo technique have the disadvantage of being able to measure the distance only from a surface and in particular from surfaces normal to the beam. If someone wants to measure the distance from a certain point, the only way he can do it is by vertically placing a flat reflecting surface at that point (which is sometimes impossible) *ie* by placing the surface normal to the line from the transmitter to the point of measurement, and thus normal to the ultrasonic beam (Figure 1).

Two problems have to be solved in such a case:

(a) It is not always possible to place a flat normal reflector at the point of measurement.
(b) Even if (a) is possible, there will always be the matter of ensuring the accuracy of the normal placement of the reflector, which depends on the width of the beam.

Dihedral rectangular reflector

In the case of a dihedral rectangular reflector, if the incident plane is normal to its edge, the following two principles have been shown to be true from the field of optics[1,2]:

(a) The emerging rays from the reflector are parallel and have a direction opposite to the incoming rays (Figure 2).
(b) The path (AK + KL + LF) inside the reflector is equal to $2 \times (OA_2)$, regardless of the exact position of point K, if K lies between O and B. This path is equal to:

$$AK + KL + LF = \frac{2a}{\sqrt{2}\cos(i)}$$

where i is the angle of incidence from the normal of the frontal plane, and a is the length of the edge of the dihedral, as shown in Figure 2.

Thus, if we want to measure the distance between a transmitter T and a certain point, we have to place the top O of the reflector at that point and point to the reflector from the transmitter. The beam returns to the transmitter which measures the distance T–O. When the angle of incidence (i) changes, the distance T–O remains constant (the distance inside the reflector increases but that outside the reflector decreases by the same amount).

Trihedral rectangular reflector

The trihedral rectangular reflector is part of the surface of a cube that has been cut as shown in Figures 3 and 4. The properties applying to the dihedral reflector also apply to the trihedral reflector. This means that the incoming rays leave the reflector, after a triple reflection, parallel and in the opposite direction to the incoming ones. The paths of all the rays of the beam inside the reflector are equal to one another and also equal to twice

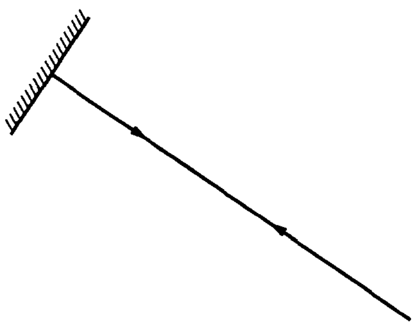

Figure 1 Front surface, mirror as a reflector

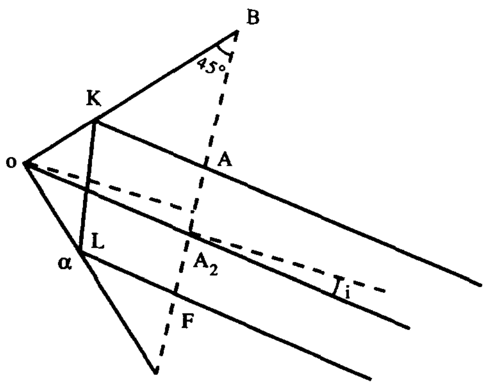

Figure 2 Paths of the rays in a rectangular dihedral reflector

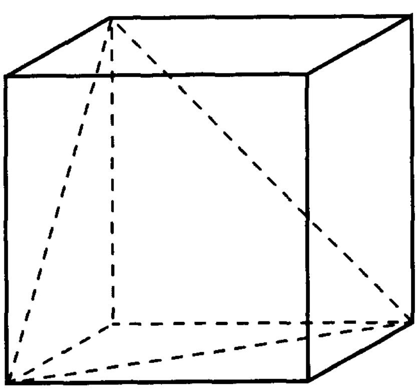

Figure 3 Intersection of a cube for the creation of a trihedral rectangular reflector

the path of the ray that ends at the top O of the trihedral. The length of the path is equal to $[2a/(\sqrt{3}\cos(i))]$, where a is the length of the trihedral's edge and i is the angle of incidence from the normal of the frontal plane.

For the measurement of the distance via this reflector a procedure similar to that for the dihedral reflectors has to be followed.

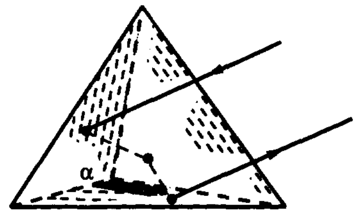

Figure 4 Trihedral rectangular reflector

We place the top of the reflector at the point whose distance we want to measure and point there with the transmitter. The beam reflects on the interior planes of the reflector (Figure 4) and the receiver measures the distance between the transmitter and the top of the reflector. The measurement does not depend on the angle of incidence if this angle is less than 45°.

Construction

The trihedral reflector is made of Perspex, 5 mm thick. The length of each of its edges a is 12 cm. The three parts are stuck together and form a solid right-angle.

Transmitter

The transmitter used was a Dimension Master Plus from Calculated Industries Inc. It had to transmit at 50 kHz via three simultaneous transducers of 25.4 mm in diameter, in order to be able to form a narrow beam. The same transducers were used by the receiver.

Experiments

A distance was measured using a measurement tape. The transmitter was placed at one end of the tape while the internal top of the reflector was placed at the other. Repeated measurements were made, while rotating the reflector, so that the angle of incidence could be altered from 0 to 30° in all directions. Regardless of the angle of incidence, the distance measured by the transmitter remained constant (equal to the measurement derived from the tape) for as long as point O remained constant.

Many experiments were performed for distances between 1 and 20 m and their results were within the limits of error provided by the transmitter manufacturer.

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2 **Pauli, W.** 'Avantages d'un reflecteur basculant dans la telemetrie electro-optique' *Vermessungs Informationen Jena* **26** (1973) pp 9–13