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Attenuated retroreflectors for electronic distance measurement

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Abstract

This technical note describes methods for attenuating solid glass, cube corner, total internal reflection (no metallic coating on reflecting surfaces), and hollow retroreflectors, without introducing optical path length modifications. Examples of experiences with both solid glass and hollow retroreflectors are given.

Keywords: retroreflector; electronic distance measurement

1 Introduction

In some electronic distance measurement (EDM) applications, the dynamic range is such that the signal requires attenuation for close-range measurements in order to avoid non-linearities in the detector electronics. To account for time of flight or, alternatively, phase shift through the attenuator, any attenuating filter placed in the path requires a correction for the group index of refraction of the attenuating medium. Also, care must be taken to avoid the cosine theta error for the thickness. Further, additional surfaces can introduce additional reflections which can introduce phase errors and make the retroreflector sensitive to orientation.

2 Attenuated solid glass retroreflector

The model PSH97 ranging instrumentation, designed and built for the Robert C. Byrd Green Bank Telescope[1, 2, 3, 4], incorporates a fixed, solid glass, reference retroreflector used to correct for electronic

phase drift of the instrument. Solid glass cube corner, total internal reflection (TIR), retroreflectors were chosen for their robust mechanical properties, because the instruments operate in outdoor conditions and experience condensation and temperature extremes. However, the unattenuated close-range reference path return signal saturated the detector electronics. Care also had to be taken to direct the front-surface reflections away from the detector.

A number of ideas were explored, but it was desirable to retain the ability to calibrate the retroreflectors from first principles, i.e., thickness of the glass. It was discovered that this was easily accomplished by contaminating the back surfaces of the TIR retroreflector. With a little experience, the desired signal range could be achieved by spraying a light mist of paint above the reflecting cube corner surfaces of the retroreflectors to create a speckled overspray. Initial trials, which over-attenuated the signal, were easily recovered by simply cleaning the paint from the robust glass corner cube. Scatter from the contamination is unlikely to be returned to the detector, so no phase error is introduced. Note that the retroreflector dimensions (distance from the apex to the center of the front face) must be measured before speckling.

3 Attenuated hollow retroreflector

For an independent check of the distance from the instrument steering mirror axes to the reference retroreflector, an attenuated hollow retroreflector was desired, since it can be calibrated mechanically, from first principles. This was achieved by a modification to the standard PLX Corporation hard mount retroreflector design[5, 6]. In this modified design, one of the first surface mirrors was replaced with a flat, OD 3 (transmission = 10^{-3}), neutral density filter, i.e., instead of reflecting off an aluminized mirror, about 1% of the power is reflected off the front sur-

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face of the glass and the remaining power is absorbed by the filter. By using an absorbing type neutral density filter material, the additional reflections off the rear surface are virtually eliminated (the OD 3 filter is effectively an OD 6 for the double pass).

Two, 1 inch retroreflectors of this design were custom built for NRAO, by PLX. Since all retroreflected beams undergo a reflection at all three mirrors, additional surfaces could also be substituted for compounded attenuations. Calibration of the retroreflector mechanical apex (virtual reflection point) remains the same, as with the standard hollow retroreflector[7].

Reflections from the front surface of the glass filter, unlike the metal mirrors, introduce polarization rotations which can introduce further attenuation if the detector input is polarization sensitive, e.g., if an isolator is used on the detector. Moreover, the reflection coefficient is angle of incidence dependent. By rotating the retroreflector about the optical axis, the polarization and angle of incidence (and thus reflection coefficient) are modulated, which can be used to adjust the attenuation.

4 Transient attenuation

If one wishes to introduce a transient attenuation, such as when conducting a test of the sensitivity of the distance measurement to signal amplitude, a simple test can be conducted by misting a light fog onto the retroreflector under test. For example; by exhaling on the retroreflector (with proper eye protection), or placing a cup of hot water next to the retroreflector, a light mist will condense on the cool reflecting surfaces which will effectively kill the reflected power. This will rapidly evaporate away. By recording the distance measurement and power levels as the mist evaporates, a plot of distance vs power level can be constructed.

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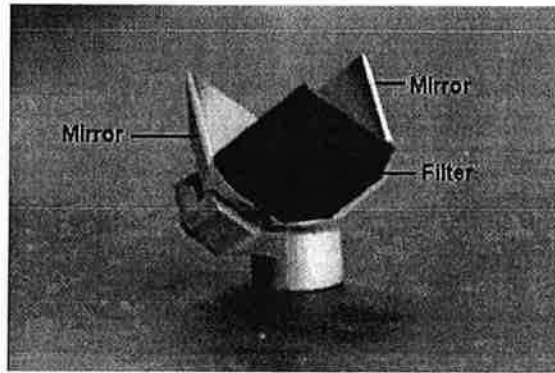


Figure 1: Attenuater hollow retroreflector.

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