**Subject:** FW: Cubes
**Date:** Friday, September 15, 2017 at 1:15:02 PM Eastern Daylight Time
**From:** David Arnold
**To:** Giuseppe Bianco
**Attachments:** Case11,12.pdf

Mike asked for a list of the reasons for going to small cubes.

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On 9/15/17, 1:08 PM, "David Arnold" <david-arnold2006@earthlink.net> wrote:

Mike,

1.5 inch cubes were used on LAGEOS solely for financial reasons. The analysis showed that a larger number of smaller cubes would give much better results for both optical and thermal reasons. Because the cost is the same regardless of size using a large number of small cubes would have been much more expensive. The accuracy goal at that time was 5 mm. The 5 mm accuracy could be obtained despite the problems with the larger cubes. Now the accuracy goal is one millimeter. The present geodetic satellites cannot provide this level of accuracy.

A larger number of small cubes is a better approximation to a uniform reflecting surface. The variation of the range correction with incidence angle on the satellite is reduced.

The 1.5 inch cubes are too large for the velocity aberration. The beam spread has to be increased by adding dihedral angle offsets. This produces a "lumpy" diffraction pattern that causes variations in the range correction within the far field diffraction pattern.

In an uncoated cube the dihedral angle offsets interact with polarization effects from total internal reflection to give an asymmetrical diffraction pattern and range correction matrix if linear polarization is used. The range correction depends on the angle between the polarization and the velocity aberration. The produces a systematic error larger than one millimeter that is not accounted for in the analysis.

By properly selecting the size the necessary beam spread can be obtained without dihedral angle offsets. This eliminates most of the asymmetry in the range correction with linear polarization. There is no significant error due to asymmetry of the range correction with linear polarization.

In uncoated cubes polarization effects create a ring of spots around the central peak. The provides more beam spread in a natural way. The diffraction pattern is much smoother than with dihedral angle offsets. This ring of spots can be placed at the velocity aberration range 32 – 40 microradians using a 1.0 inch uncoated cube with no dihedral angle offset.

The ring around the central peak is a very stable part of the diffraction pattern. Changes in thermal gradients or dihedral angle offsets have a significant effect on the central peak (which is never observed because of velocity aberration). However, the cross section between 32 and 40 microradians does not change much.

Thermal effects increase as some power (probably the 4th power) of the size of the cube. For example, the phase change for a linear temperature gradient in a cube increases as the square of the length of the cube. The effect of a phase change on the diffraction pattern is also approximately quadratic for small phase changes. The simulations show that variations in the cross section decrease by about a factor of 5 or 6 going from a 1.5 inch to a 1.0 inch cube.

The financial problem with using a large number of small cubes has been removed by the availability of inexpensive COTS (Commercial Off-The-Shelf) cubes. Testing done by Ludwig Grunwaldt shows that the optical quality of these cubes is as good as custom made cubes. Simulations done with actual measured dihedral angle errors in these cubes show that these unintentional offsets do not significantly degrade the range accuracy.

Because the mean dihedral angle offset is zero, and the effects of a + and - offset are in opposite directions, there is some cancellation of the effects of the unintentional + and – angle offsets.

Thermal simulations show that with a floating mount the effect of thermal gradients is very small. The isothermal calculations of the range correction will accurately predict the actual performance in space.

The thermal effects are much larger if there is conductive contact between the retaining rings and the cube corner. The gap between the ring and the cube could potentially cause damage to the cube because of vibration during launch. One solution would be to restrain the position of the cube with a spring. This would introduce conduction that would degrade the optical performance. However, vibration tests with a large gap show no damage to the cubes. This floating mount is mechanically feasible.

Because the range correction is on a natural peak of the diffraction pattern, rather than on a steep slope, the cross section and range correction do not vary much over the velocity aberration range of 32 to 40 microradians. The variation is on the order of .5 mm. In principle even this variation could be removed by applying a correction vs velocity aberration.

The attached file shows the cross section vs velocity aberration for a floating mount (Case 11) and with conductive contact (Case 12). The variations between 32 and 40 microradians are quite small and in opposite directions as the sign of the dihedral offset changes.

Best,

David Arnold

On 9/15/17, 11:51 AM, "Michael R. (Mike) Pearlman" <mpearlman@cfa.harvard.edu> wrote:

David

Give me the words as to why we should go to the 1 inch cubes.

Mike

Sent from my iPhone